Tappi

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OCTOBER 1955

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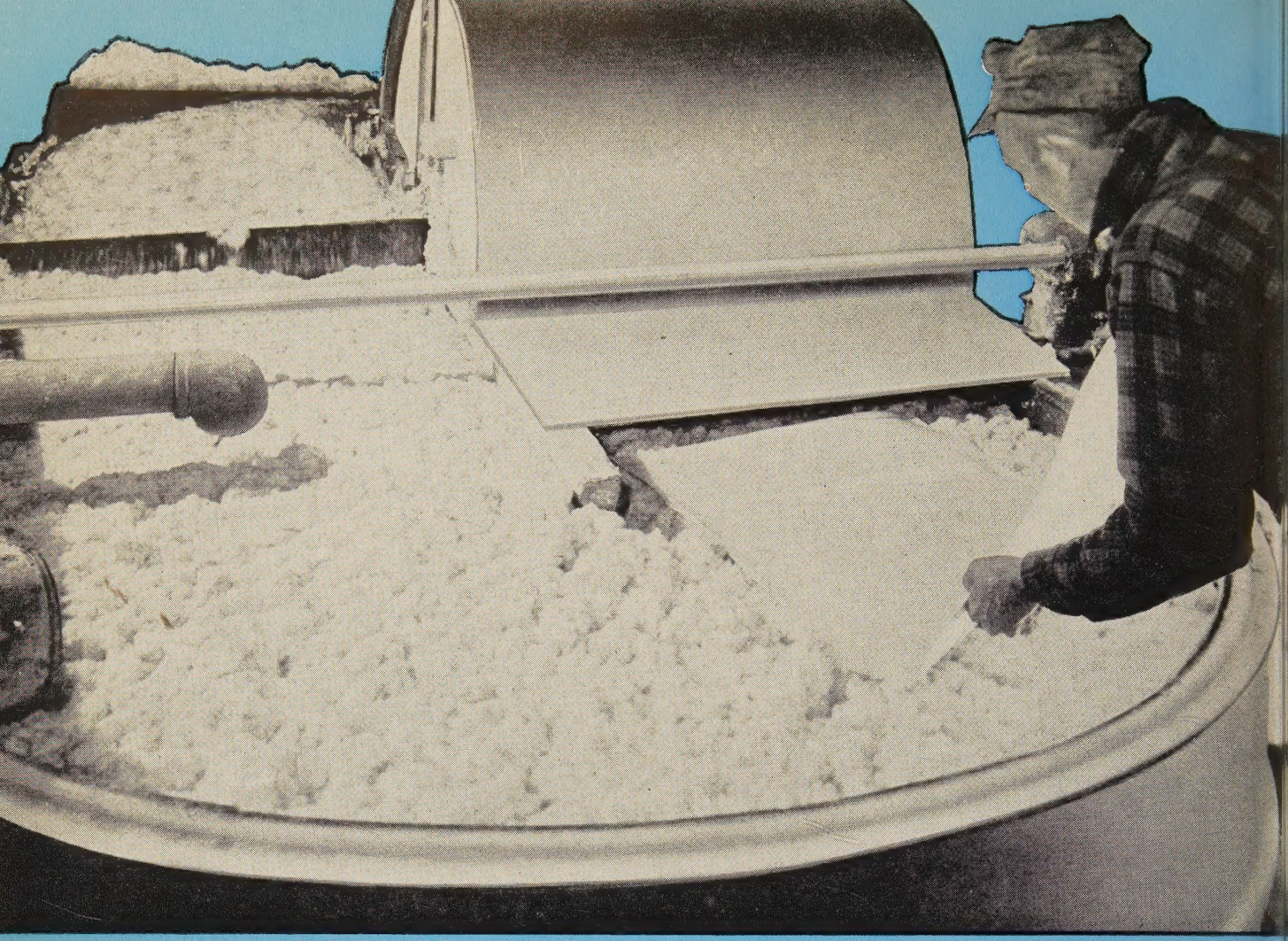

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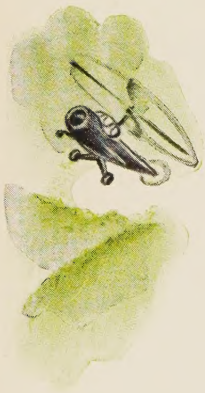

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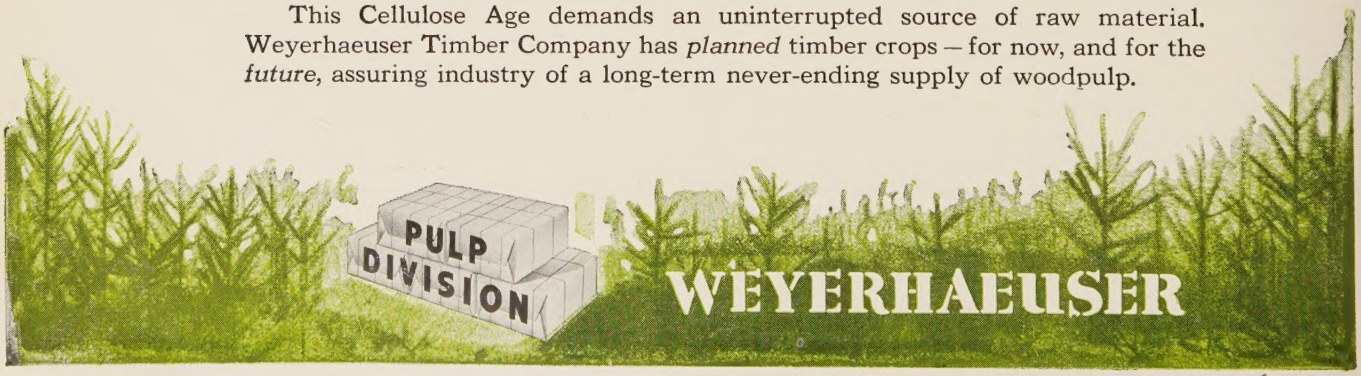
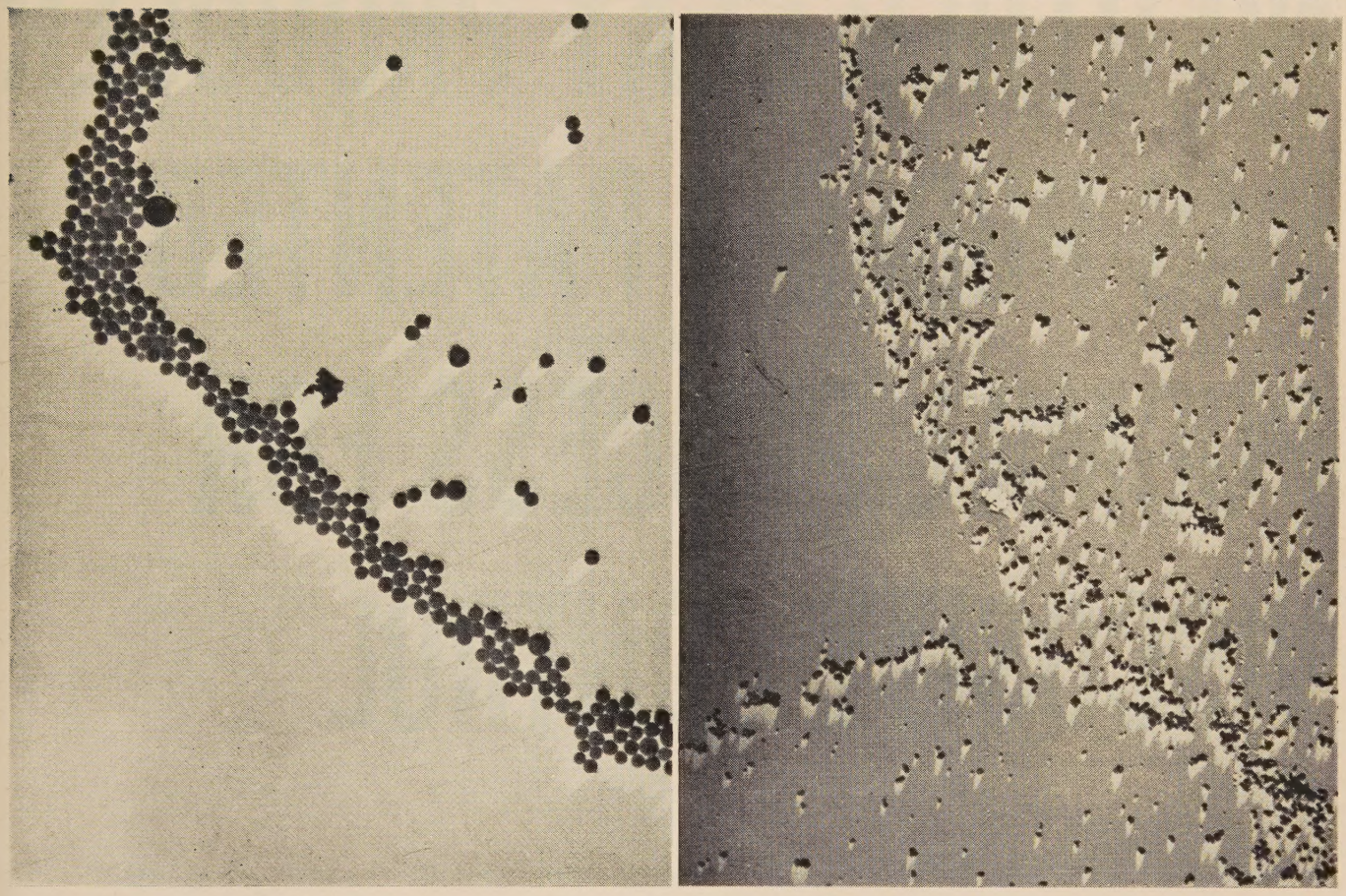


ELECTRON PHOTOMICROGRAPHS (10,000X) compare normal size latex particles (left) approximately 0.25 micron (2500Å) in diameter, with those of new, small-particle size CHEMIGUM LATEX, approximately 0.05 micron (500Å) in diameter.



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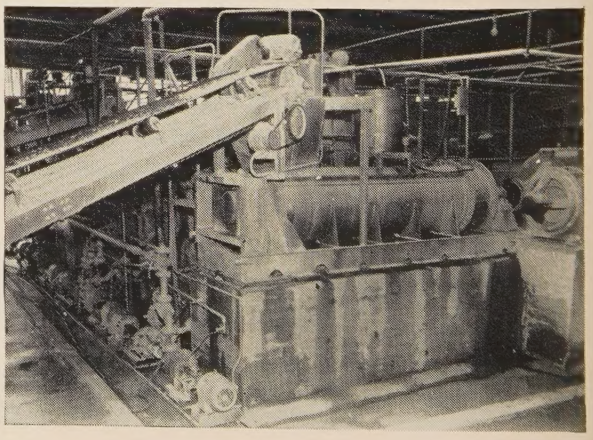

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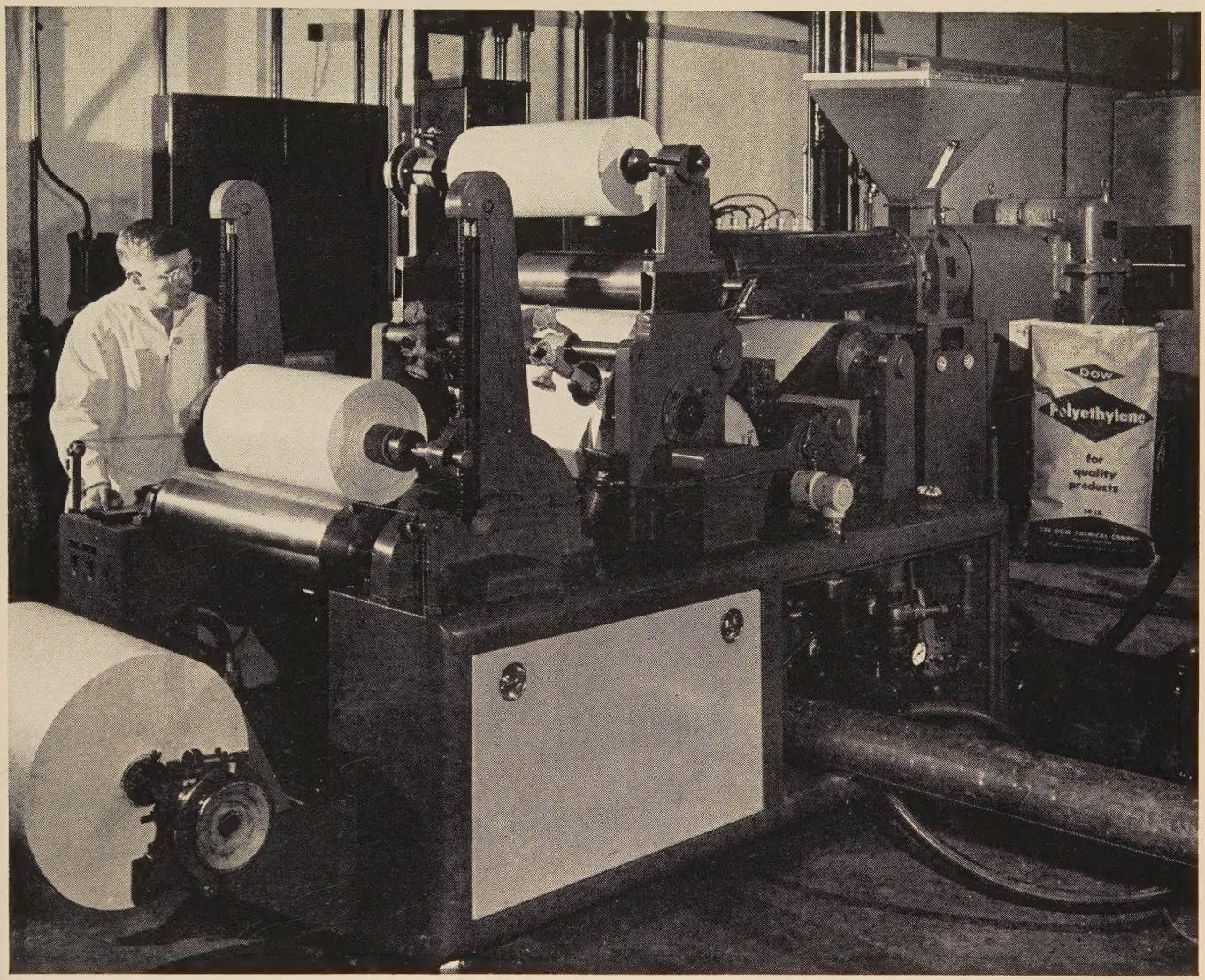

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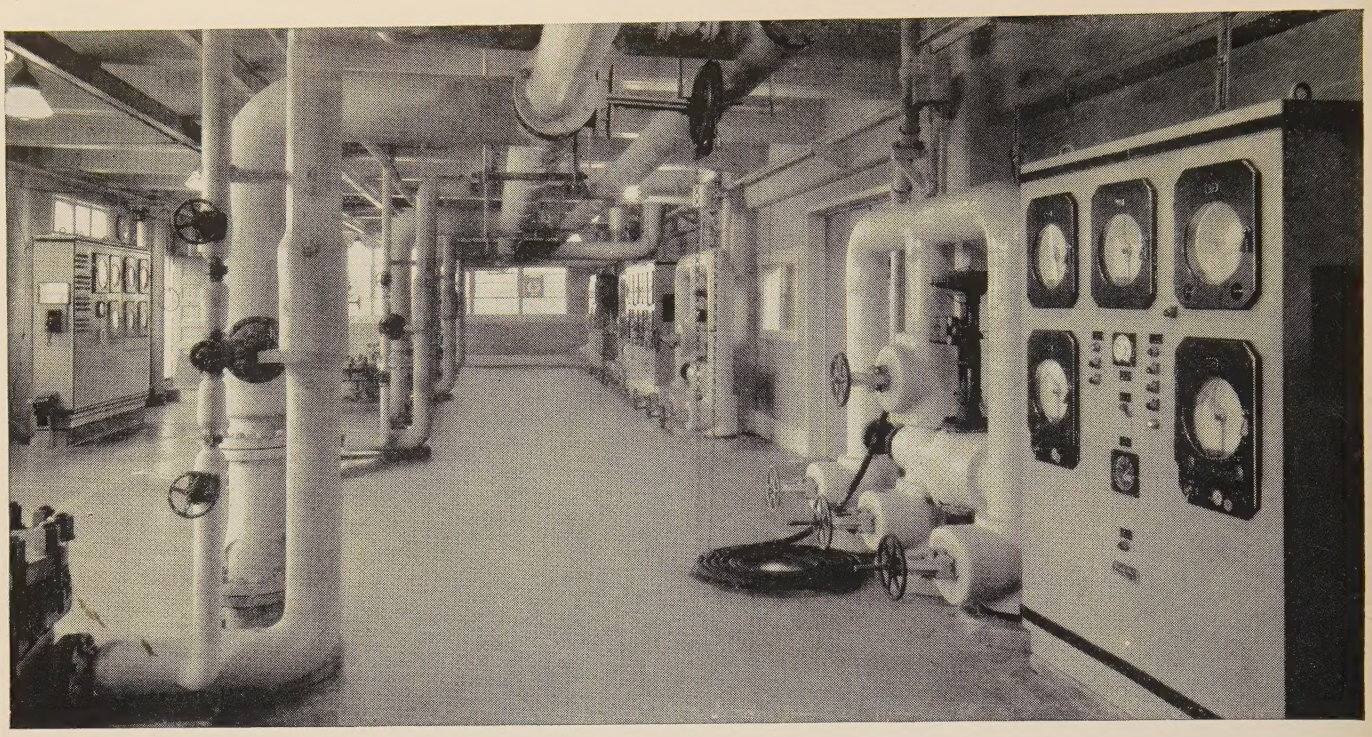

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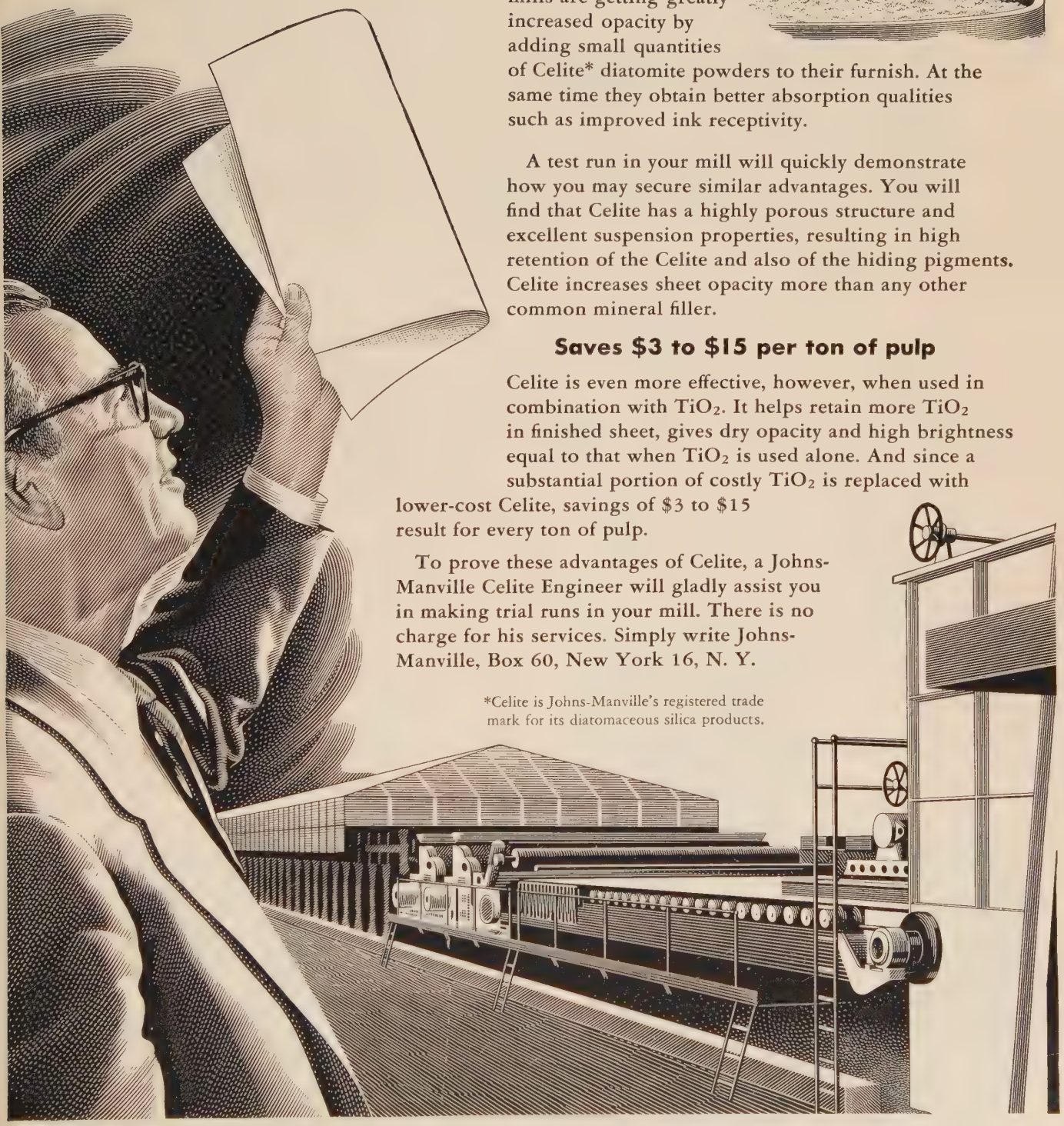

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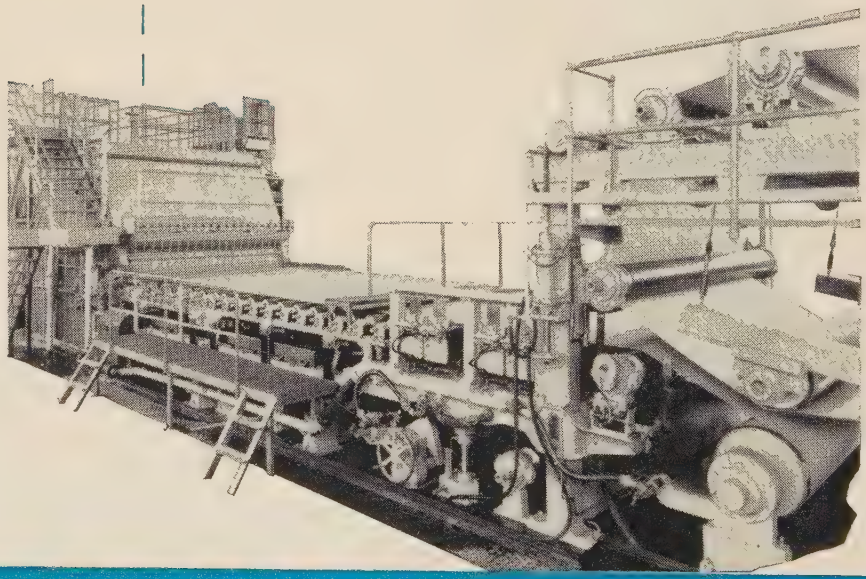

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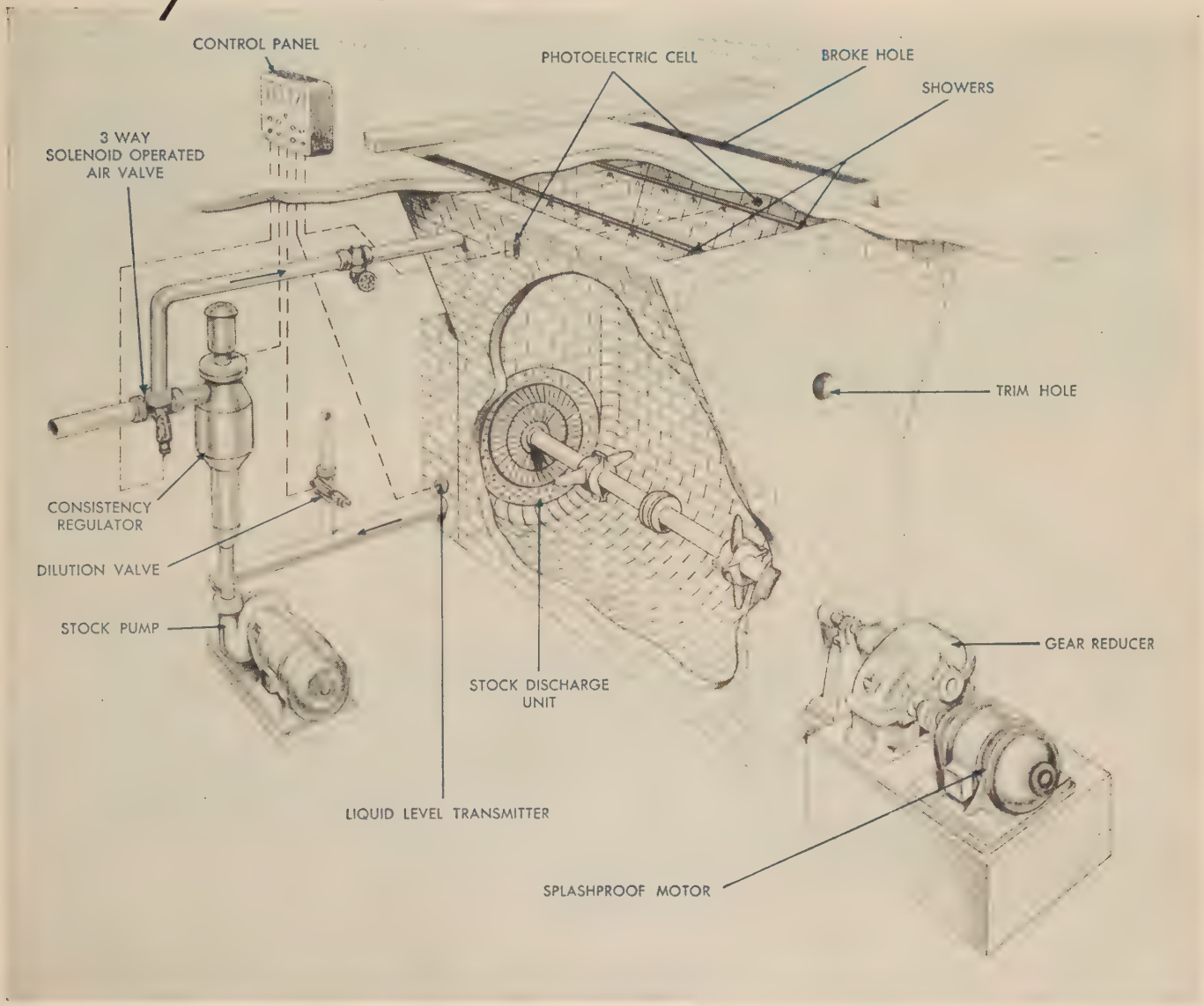

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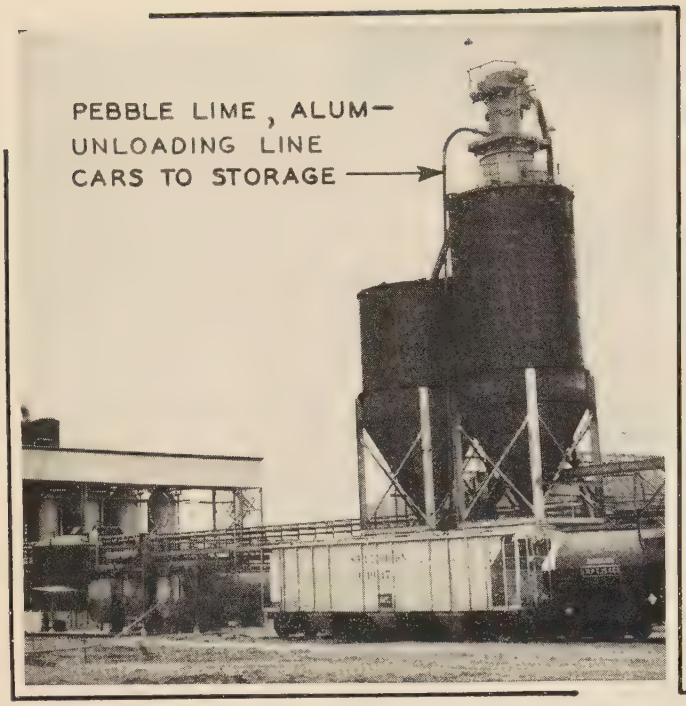

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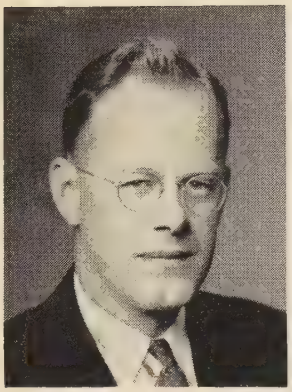
The Groundwood Economy

J. L. RITCHIE



J. L. Ritchie

MORE than a hundred years have passed since a German by the name of Keller first produced mechanical wood pulp. Today, a full century later, 35% of the world's wood pulp supply is produced mechanically by processes that have evolved from Keller's original idea.

Over the years, three factors have been primarily responsible for the remarkable growth, not only of the mechanical wood pulp industry, but of the whole pulp and paper economy: (1) progress in wood utilization; (2) improvements in processing equipment and materials, and in processing methods; and (3) improvements in merchandise and in merchandising techniques.

Significantly, all of the papers scheduled for presentation at this Second Mechanical Pulping Conference fit neatly into one or another of these three categories. The formula for progress has not changed.

There have been changes, however, in the methods for applying the formula. These meetings suggest a growing faith in the value of the conference technique. The technical man, to his credit, was among the first to acknowledge that he could not work effectively in a vacuum. Since the war, we have seen, in all lines, a healthy trend toward a freer world-wide exchange of knowledge and ideas. In this trend lies real hope for an acceleration of technical, economic, and social progress throughout the world.

The scope of the program for this conference suggests that we are still a long way from exhausting the full potentialities of Keller's basic century-old idea. I can assure you that I have neither the intention nor the capacity to exhaust them tonight. My instrument, as you know, is the telescope—not the microscope. My sole objective will be to try to bring into focus some of the basic industry trends, to take some measurements of the groundwood economy, and to examine the position of mechanical pulps in the over-all pulp and paper economy.

WOOD UTILIZATION

Ever since wood became the primary raw material for papermaking, the pattern of growth in the domestic wood pulp industry has been pretty much dictated by the character of the existing wood supply. In general, growth rates have been greatest in those segments of the industry that have been most flexible in adjusting their operations to the types of wood that grow.

J. L. RITCHIE, Executive Director, United States Pulp Producers Assoc., Inc., New York, N. Y.

Conventional pulping species have traditionally been used for paper production as long as they have been available in volume adequate to support growth; whenever it became apparent that conventional species were no longer adequate to support new capacity, some segment of the wood pulp industry was smart enough to learn how to use unconventional species. The pulps produced from these unconventional woods were different, of course. *That* problem, however, became one for the paper department. The challenge presented by pulps with new and different characteristics has always been quickly met in this country, not only by paper producers, but by the ultimate consumers of paper products as well. Despite shifts in the grade pattern of pulp consumption, necessitated by changes in the pattern of available wood supply, the range of pulp products has been constantly broadened and the quality of these products steadily improved.

The wood pulp industry was, of course, suckled on spruce; for years, spruce remained the primary fibrous raw material for wood pulp. The domestic pulp and paper industry was originally centered near the great spruce forests of the northeast; until 1936, Maine and New York led the country in pulp production.

Quite early in the industry's history, it became apparent that the available supplies of spruce in this country would not long support the anticipated growth in paper requirements. Hemlock and fir were drafted to supplement the supply of pulpwood for sulphite and mechanical pulp production, and poplar for soda pulp production. As late as 1914, however, spruce was still supplying over 65% of the industry's over-all pulpwood requirement.

Because of the industry's heavy reliance upon spruce and because forestry experts could not foresee where the wood was coming from to support adequate growth of the domestic pulp and paper industry, the United States Congress in 1914 acted to remove the tariff on wood pulp and newsprint. The purpose and the effect of this action was to open up to the vast spruce forests of Canada the fast-growing American market. Profiting by this action, wood pulp producers in Canada more than quadrupled their pulp production in the next 15 years; the increase in United States production during this same period was a relatively modest 46%. Because of limited progress in wood utilization, the economics of expansion continued to favor Canada until 1929. By 1929, Canada was producing 45% of North America's total pulp production as contrasted with 24% in 1914.

During the 1920's, however, United States pulp producers had been experimenting with new wood species—notably Douglas-fir in the west and southern pines in the south. Success in the utilization of these species by the kraft process opened up for the domestic industry a tremendous new raw material supply.

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Largely because of this broadening of the species base, wood pulp production in the south and west tripled in the 1920 decade, while production in other regions declined.

By 1930, because of progress in fiber utilization and in market development, the economics of expansion had very definitely shifted in favor of the south and the west; as a result, wood pulp production in these two regions increased more than $3^1/_2$ times between 1930 and 1940, while production in other regions of the United Sates increased by a modest 13%, and production in Canada by a relatively modest 46%.

Table I. The Groundwood Pulp Economy of North America

(Thousands of short tons)

	1937	*1950*	*1953*	*1954*
	Production			
United States	1601	2216	2342	2429
Canada	3309	4911	5123	5279
North America	4910	7127	7465	7708
	Imports			
United States	218	280	259	239
Canada	...	1	3	4
North America	218	281	262	243
	Exports			
United States	0	...	0	0
Canada	167	248	228	232
North America	167	248	228	232
	New Supply for Home Consumption[a]			
United States	1819	2495	2602	2668
Canada	3142	4664	4898	5051
North America	4961	7159	7500	7719

[a] Production plus imports minus exports.
Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

By 1940, other important developments in the field of fiber utilization began to assume significance. Most important of these developments was the growing interest in all regions of the United States in the use of hardwoods. Not only was the kraft process adapted to their use, but new high yield pulping processes were successively introduced to take advantage of this new and abundant fibrous raw material supply source—first, the semichemical process, then processes for the manufacture of defibrated and exploded pulps, and finally the chemigroundwood process. By 1940, the production of wood pulp by these new high yield pulping processes had achieved the modest level of 225,000 tons.

The economics of World War II brought a sudden end to normal market development and expansion in the domestic pulp and paper industry. There were some production gains during the war as projects started in the late 1930's were carried through to completion and as higher operating rates prevailed in many segments of the industry. Generally speaking, however, wartime economics frowned upon any expansion of North American pulp and paper facilities.

Prewar progress in fiber utilization paved the way, however, for a postwar expansion program that was to prove the greatest in the domestic industry's history. Since World War II, productive capacity in the United States wood pulp industry has increased by more than 10 million tons—from 12 million tons to over 22 million tons. Of this 10 million ton capacity increase, 60% has been in kraft, 20% in the new high yield pulping processes, about 10% in groundwood, and about 10% in dissolving and other chemical pulp grades.

It is significant that 80% of the domestic pulp industry's postwar growth has been in those segments of the economy in which research in fiber utilization has been most actively pursued—in kraft, and in the high yield pulping processes that rely primarily upon hardwoods.

In the general effort to broaden the species base, the mechanical pulp segment of the industry has been far from inactive. Defibrated and exploded pulps are, of course, mechanically produced. Their introduction in the 1930's opened the way for substantially increased hardwood utilization. United States capacity for the

Table II. North American Wood Pulp Production

(Thousands of short tons)

	Groundwood	*Total, all grades*	*Groundwood as % of total*
	Canadian Wood Pulp Production		
1909	326	445	73.3
1914	645	935	69.0
1919	991	1716	57.8
1921	932	1549	60.2
1926	1901	3230	58.9
1929	2421	4021	60.2
1933	1825	2980	61.2
1937	3309	5142	64.4
1945	3342	5601	59.7
1946	3998	6615	60.4
1950	4911	8473	58.0
1951	5172	9315	55.5
1952	5175	8968	57.7
1953	5123	9077	56.4
1954	5279	9626	54.8
	United States Wood Pulp Production		
1909	1179	2,496	47.2
1914	1294	2,893	44.7
1919	1591	3,518	45.2
1921	1260	2,876	43.8
1926	1764	4,395	40.1
1929	1638	4,863	33.7
1933	1198	4,276	28.0
1937	1601	6,573	24.4
1945	1827	10,167	18.0
1946	1951	10,607	18.4
1950	2216	14,849	14.9
1951	2474	16,524	15.0
1952	2321	16,473	14.1
1953	2342	17,537	13.4
1954	2429	18,348	13.2
	North American Wood Pulp Production		
1909	1505	2,941	51.2
1914	1939	3,828	50.7
1919	2582	5,234	49.3
1921	2192	4,425	49.5
1926	3665	7,625	48.1
1929	4059	8,884	45.7
1933	3023	7,256	41.7
1937	4910	11,715	41.9
1945	5169	15,768	32.8
1946	5949	17,222	34.5
1950	7127	23,322	30.6
1951	7646	25,839	29.6
1952	7496	25,441	29.5
1953	7465	26,614	28.0
1954	7708	27,974	27.6

Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

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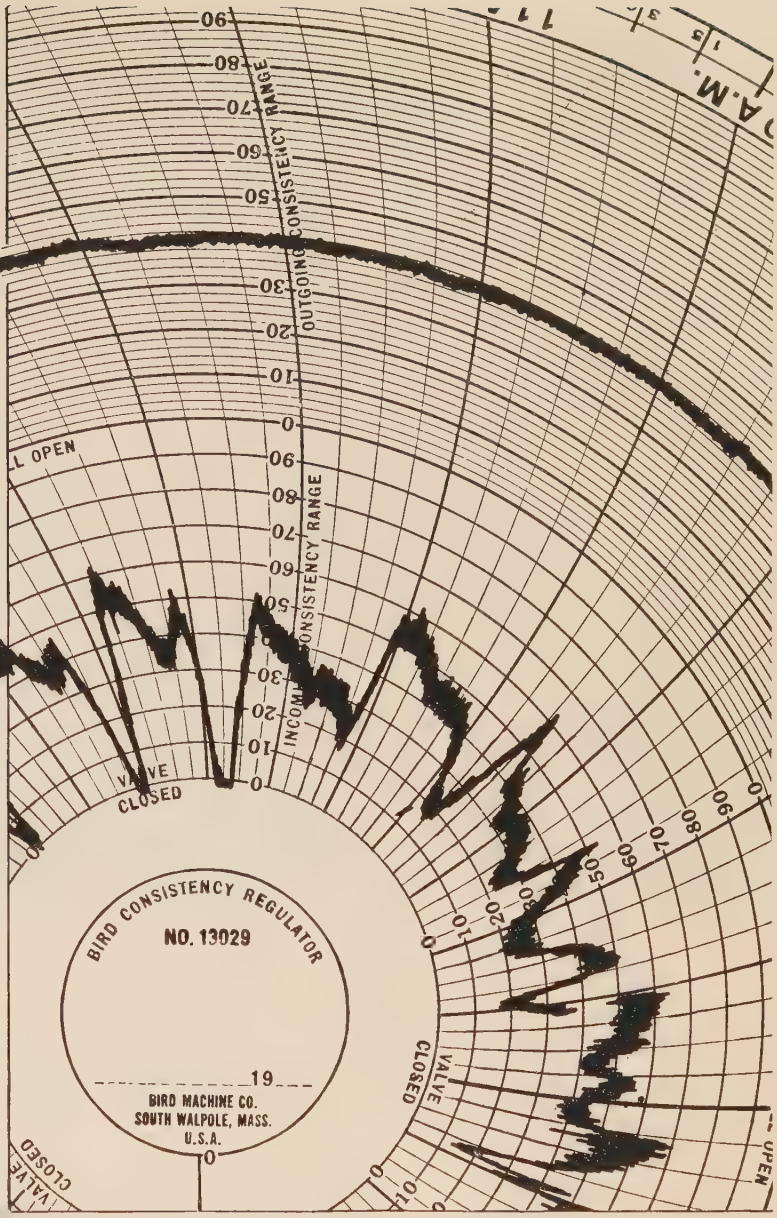

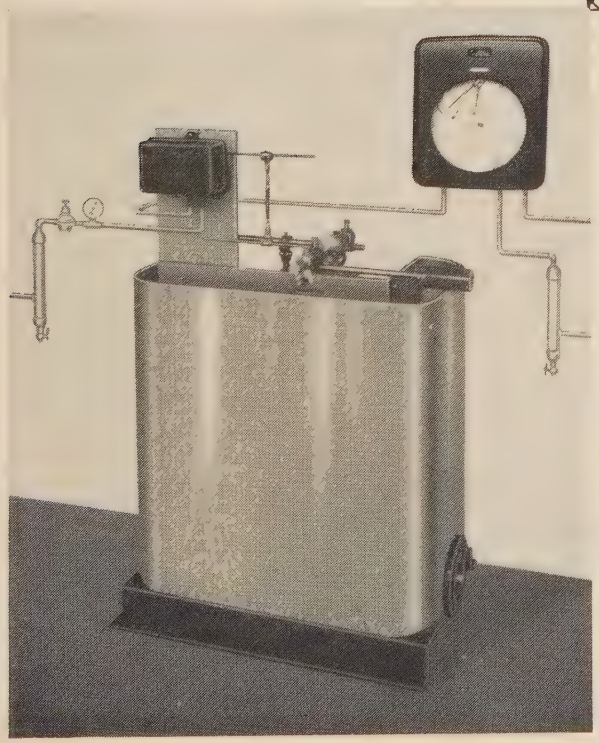

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production of these grades, on an annual basis, is now approaching $1^1/_2$ million tons.

Mechanical defibration is also, involved, of course, in semichemical pulp manufacture. The process might with equal aptness have been called the semimechanical process. United States capacity for the production of semichemical grades, based largely on hardwoods, will soon exceed 2 million tons.

Combined United States capacity for the manufacture of defibrated, exploded, and semichemical wood pulps, very shortly, will about equal capacity for the production of groundwood pulp itself.

The use of hardwoods in the conventional groundwood process, excepting poplar, is of relatively recent origin. Few mechanical pulp developments in recent years have attracted as much world-wide attention as the introduction of chemigroundwood. Its success,

Table III. The Groundwood Pulp Economy of Free Europe in 1954

	Thousands of short tons	*% of total*
	Total Production	
Scandinavia	2514	60
Finland	934	22
Sweden	870	21
Norway	710	17
Germany	618	15
France	342	8
Austria	170	4
Italy	163	4
All others	402	9
Total	4209	100
	Total Apparent Consumption	
United Kingdom	805	19
Finland	721	17
Germany	645	16
Sweden	476	12
France	442	11
Norway	285	7
Italy	182	4
Austria	164	4
All others	396	10
Total	4116	100
	Total Exports	
Scandinavia	1032	99
Norway	425	41
Sweden	394	38
Finland	213	20
All others	9	1
Total	1041	100
	Total Imports	
United Kingdom	677	71
France	101	11
Netherlands	66	7
Germany	26	3
Denmark	24	3
Italy	19	2
Belgium	13	1
Spain	12	1
All others	10	1
Total	948	100

Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

and its adaptations, may well tend to broaden significantly the fiber base of the world's groundwood economy.

THE GROUNDWOOD ECONOMY OF NORTH AMERICA

In view of the rapid development of newer pulping processes, it is not surprising that the ratio of groundwood production to total wood pulp production in North America has been declining rather steadily for many years.

In North America, despite the fact that production of groundwood has tripled in the last 40 years, groundwood's share of total wood pulp production declined from over 50% in 1914 to $27^1/_2$% in 1954. For the United States alone, the decline in groundwood's relative position was from 45% of total production in 1914 to 13% in 1954; for Canada alone, groundwood production declined from 69% of total in 1914 to 55% in 1954.

Table IV. Groundwood Pulp Production in Free Europe
(Tons of 2000 lb.)

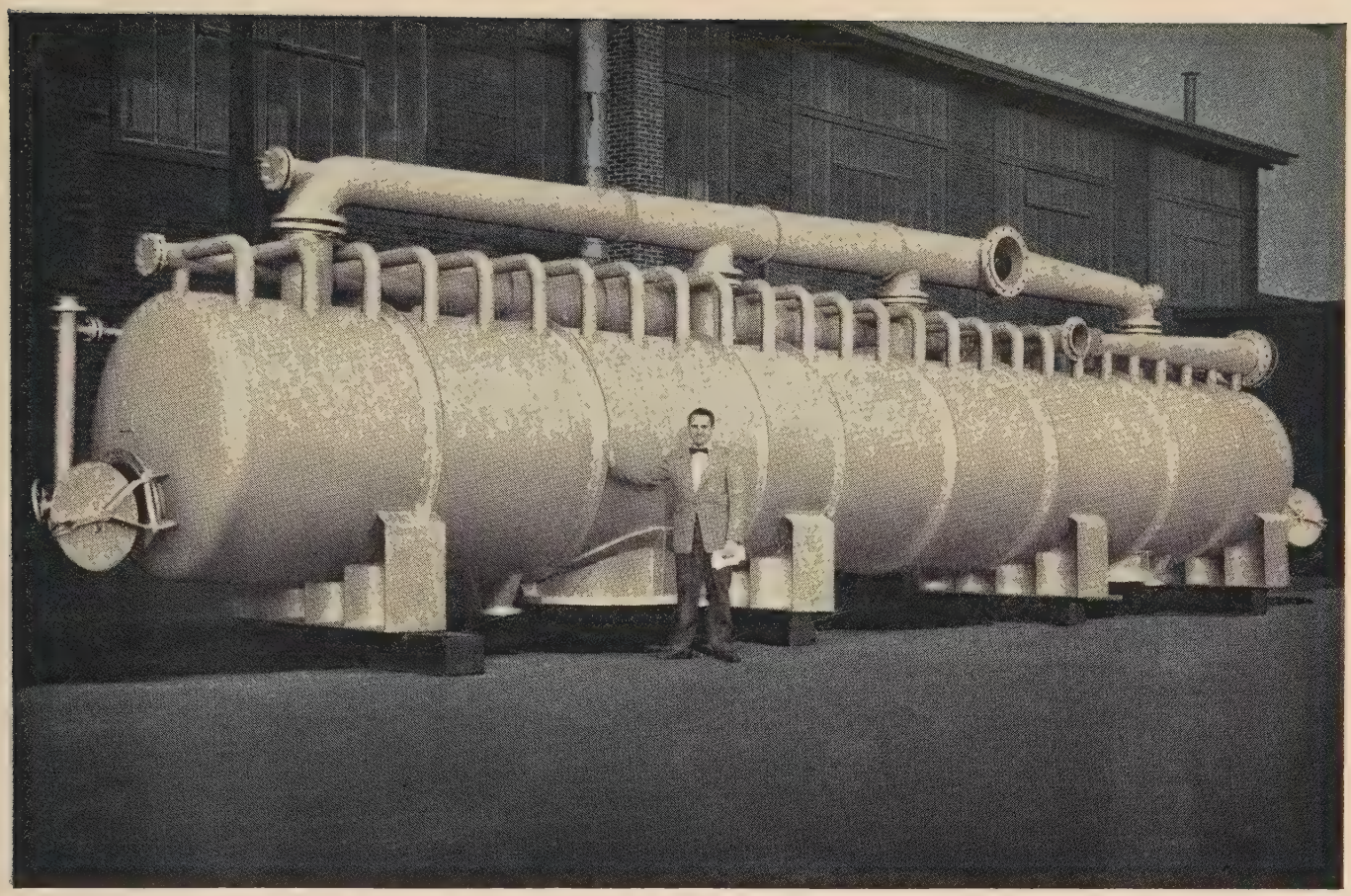
	1937	*1950*	*1953*	*1954*
Austria	121,209	102,886	140,713	169,513
Belgium	0	52,000	58,380	58,438
Denmark	6,420	952	4,825	4,065
Finland	903,724	793,010	877,113	934,415
France	276,455	318,600	300,900	341,700
Germany	1,222,000	435,000	525,231	618,422
Ireland	0	0	0	0
Italy	161,766	140,873	163,100	163,200
Netherlands	75,000 (est.)	54,000	63,000	71,000
Norway	598,958	588,517	590,260	709,699
Portugal	0	0	0	0
Spain	20,000 (est.)	21,643	23,065	25,522
Sweden	808,756	782,885	790,360	870,000
Switzerland	49,604	77,000	88,000	99,000
Turkey	3,004	6,624	9,800	16,500
United Kingdom	202,000	122,000	127,000 (est.)	128,000 (est.)
Total	4,448,896	3,495,990	3,761,747	4,209,474

Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

Canada, of course, remains the dominant factor in North American groundwood production. Last year, Canada's groundwood production was more than twice that of the United States; in the total wood pulp economy of North America, conversely, the United States is currently producing at a rate twice that of Canada. This diversity of pattern is not difficult to explain: the economics of groundwood expansion have been in Canada's favor because (1) Canada alone has had abundant supplies of the pulping species traditionally used in groundwood production; (2) Canadian newsprint, the major product of groundwood, has been able to move freely in world trade; and (3) progress in fiber utilization in the groundwood economy of the United States has been relatively slow.

That Canada will remain the dominant factor in the North American groundwood economy is a virtual certainty. Long range, however, the measure of her dominance may decline in some degree for several reasons:

1. Canada, herself, we believe, would like to diversify her pulp and paper production, not only on the theory that too many eggs in one basket can be dangerous, but also because of her desire to share in the world's trade in higher valued products. Growth in the population of Canada will tend to encourage a gradual diversification of Canadian production. It is probable, however, that the only development that could really accelerate product diversification in the Canadian pulp and paper economy would be a general



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and significant lowering of tariffs in the major paper consuming markets of the world.

2. The United States, as its appetite for groundwood products increases, may, long range, supply a

Table V. Groundwood Pulp Imports of Free Europe
(Tons of 2000 lb.)

	1937	1950	1953	1954
Austria	0	0	0	467
Belgium	31,332	32,890	14,779	12,790
Denmark	9,617	22,107	23,877	24,489
Finland	0	0	0	0
France	173,834	105,622	73,919	100,657
Germany	162	15,000	15,755	26,257
Ireland	0	0	0	5,238
Italy	5,138	40,569	19,211	19,044
Netherlands	14,955	36,070	49,517	66,471
Norway	0	0	0	0
Portugal	3,000 (est.)	3,553	2,782	3,000 (est.)
Spain	6,000 (est.)	8,722	17,270	11,806
Sweden	1,427	0	0	0
Switzerland	139	46	657	640
Turkey	0	1,100	0	0
United Kingdom	819,008	557,567	626,937	677,161
Total	1,064,612	823,246	844,704	948,020

Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

relatively larger proportion of its own groundwood pulp requirements than it has in the past. In recent years, the United States industry has learned how to use both southern pine and hardwoods in the manufacture of groundwood. Largely because of this, groundwood pulp production which had remained virtually dormant for 25 years preceding World War II, began to show new signs of life immediately following the war. Production during 1955 has been at an annual rate that exceeds the 1945 level of production by one third. If the current production rate is maintained, United States production this year will total over 2.6 million tons, 9% higher than last year.

United States consumption of groundwood pulp totaled about 2.7 million short tons last year. Specific data showing the pattern of consumption in the end products of groundwood will not be available until the results of the 1954 Census are published. Based on end-product production, however, we estimate, very roughly, that newsprint used about a million tons of last year's groundwood pulp supply, groundwood printing and specialty products another million tons, and all other grades (building board, bending board, other paperboard, tissue, and molded pulp products) the remaining 700,000 tons. This is not, of course, the consumption pattern of a typical self-contained groundwood economy; because of its heavy dependence upon imported newsprint, however, the United States is not a self-contained groundwood economy. Considering the groundwood content of imported end products, it is perhaps a fair assumption that at least 74% of the direct and indirect groundwood pulp consumption of the United States is in newsprint. In every self-contained groundwood economy, newsprint is, of course, the dominant groundwood product, and by far the major outlet for groundwood pulp.

Looking ahead, we anticipate that the most favorable growth rate among the many end-product segments of the groundwood economy will continue to be in newsprint and groundwood printing paper. Current expansion programs in the United States appear to confirm this. On the other hand, because of the trend toward an enrichment of paper furnishes in recent years, we suspect, although we cannot confirm it statistically, that groundwood pulp may have suffered a decline in relative importance in the furnish of certain end products. This could be particularly true of domestically produced tissues where the trend toward upgrading appears to have been particularly pronounced since the war; it could also be true of paperboard for packaging.

At the low end of the quality scale, groundwood products, long range, will probably face growing competition from the products of wastepaper. The spectacular growth of paper consumption in this country has operated to increase significantly the recoverable supply of wastepaper. The wastepaper salvage rate in this country has declined steadily since the war; it is currently close to an all time low. Further, because of the trend toward the enrichment of paper furnishes, the fiber content of this recoverable wastepaper supply is much richer than it used to be. At some point, the economics of paper production may dictate significant increases in the utilization of wastepaper. The wastepaper salvage rate, long range, may have a direct bearing on the relative demand for groundwood and other short fibered pulps for low end products.

At the high end of the quality scale, on the other hand, the groundwood economy will make a strong bid to improve its competitive position. Not only has there been steady improvement in the qualities of groundwood pulps, permitting commensurate improvements in conventional groundwood products, but the introduction of bleached groundwood is presenting new opportunities for market development. Progress in groundwood bleaching may well continue to give impetus to increased groundwood consumption in the printing paper field. At the present time, about 17%

Table VI. Groundwood Pulp Exports of Free Europe
(Tons of 2000 lb.)

	1937	1950	1953	1954
Austria	23,012	7,116	10,559	5,498
Belgium	0	0	0	0
Denmark	0	0	0	0
Finland	320,312	195,443	224,353	212,938
France	270	54	0	20
Germany	192	0	12	17
Ireland	0	0	0	0
Italy	0	0	0	0
Netherlands	0	0	0	0
Norway	353,928	343,801	339,455	424,985
Portugal	0	0	0	0
Spain	0	0	0	0
Sweden	389,173	312,010	341,817	394,257
Switzerland	1,863	2,928	5,287	3,611
Turkey	0	0	0	0
United Kingdom	0	0	0	0
Total	1,088,750	861,352	921,483	1,041,326

Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

of this country's groundwood pulp production is being bleached.

The groundwood economy of North America is, of course, predominantly integrated. The volume of North American groundwood pulp produced for sale

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last year totaled only 209,000 tons equal to only 2.7% of North America's total groundwood pulp production. Of this modest market pulp production, only about 4% was shipped overseas, all of it from Canada.

North America's imports of groundwood pulp from overseas are also nominal. Last year, they totaled only 37,000 tons, equal to less than $^1/_2$ of 1% of North America's total requirement for consumption.

Thus groundwood pulp is not, in any substantial measure, a long-distance traveler. The tendency, both here and abroad, is for each of the major continents to aim at continental self-sufficiency in respect to their groundwood pulp requirements.

THE GROUNDWOOD ECONOMY OF FREE EUROPE

Free Europe, like North America, has for years been self-sufficient in respect to its groundwood pulp requirements. Last year, the countries of Free Europe produced 4.2 million tons of groundwood pulp; they consumed 4.1 million tons.

Of free Europe's total production in 1954, Sweden, Finland, and Norway together produced 60%, Germany 15%, France 8%, Austria and Italy each 4%, and others 9%.

Of the consuming countries, Britain last year ranked first, consuming 19% of the total supply; Finland consumed 17%, Germany 16%, Sweden 12%, France 11%, Norway 7%, Italy and Austria each 4%, and the remaining countries 10%.

Intra-continental trade in groundwood pulp is far more extensive in Europe than it is in North America. Combined exports of the countries of Free Europe totaled 1,041,000 tons last year. The three Scandinavian countries accounted for 99% of these exports. Combined imports totaled 948,000 tons last year; of these, the United Kingdom took 71%, France 11%, the Netherlands 7%, Germany and Denmark each 3%, and all others 5%.

Table VII. Apparent Consumption[a] of Groundwood in Free Europe

(Tons of 2000 lb.)

	1937	*1950*	*1953*	*1954*
Austria	98,197	95,770	130,154	164,482
Belgium	31,332	84,890	73,159	71,228
Denmark	16,037	23,059	28,702	28,554
Finland	583,412	597,567	652,760	721,477
France	450,019	424,168	374,819	442,337
Germany	1,221,970	450,000	540,974	644,662
Ireland	0	0	0	5,238
Italy	166,904	181,442	182,311	182,244
Netherlands	89,955	90,070	112,517	137,471
Norway	245,030	244,716	250,805	284,714
Portugal	3,000	3,553	2,782	3,000
Spain	26,000	30,365	40,335	37,328
Sweden	421,010	470,875	448,543	475,743
Switzerland	47,880	74,118	83,370	96,029
Turkey	3,004	7,724	9,800	16,500
United Kingdom	1,021,008	679,567	753,937	805,161
Total	4,424,758	3,457,884	3,684,968	4,116,168

[a] Production plus imports minus exports.
Source: "Wood Pulp Statistics" (1955 edition), United States Pulp Producers Assoc., Inc.

Groundwood is relatively more important in the total pulp economy of Europe than it is in the total pulp economy of North America. As contrasted with the North American ratio of 27$^1/_2$%, groundwood pulp production in Free Europe last year was equal to 36% of total wood pulp production. There are perhaps two primary reasons for this diversity of pattern: (1) because of wood problems and economic problems generated by the war, increases in the production of chemical pulps have not been so great in Europe as in North America; and (2) because of problems of wood supply, some countries of Europe appear to be producing relatively more groundwood because of its higher yields.

The groundwood economy of Free Europe has made notable gains in recent years. Between 1950 and 1954, the consumption of groundwood pulp in Free Europe increased by 19%. Despite this gain, however, the 1954 level of consumption in Free Europe was still 7% below that of 1937, as contrasted with North America's gain of 55% during the same period.

The next few years will witness a rather sharp expansion of newsprint capacity in Europe. Increases in capacity for the production of other end products are also pending. As a consequence, there are bound to be commensurate increases in Europe's requirements of groundwood pulp.

THE FUTURE OF MECHANICAL PULPS

The gains that have been made by the mechanical pulp industry in wood utilization, in pulping processing, in pulp qualities, and in market development, afford promise that these pulps will more than hold their own in the competitive fiber economy of the future.

In the United States industry, for example, the Stanford Research Institute predicted about a year ago that this country's over-all wood pulp requirement would double between 1952 and 1975. It projected the pattern of growth in domestic pulp requirements during this period as follows:

Unbleached sulphate	+60%
White chemical pulps	+70%
Groundwood	+96%
Defibrated and exploded	+182%
Semichemical	+550%

On this basis, the high yield pulps produced in whole or in part by mechanical processes—including groundwood, defibrated, exploded, and semichemical—would constitute 39% of the total pulp supply available for United States consumption in 1975; in 1952, these same pulps constituted only 26% of total pulp supply.

In view of the fact that the situation in respect to wood supply is more stringent in Europe than it is in North America, there is reason to believe that the emphasis on high yield grades will be as great in the European fiber economy as it is here.

In conclusion, my major point of emphasis, is that relative performance by the major segments of the world's fiber economy will be determined by their relative skill in producing useful products out of the types of wood that grow—with due regard, of course, for cost factors that affect the saleability of these products in competitive markets. In the practical business world, whether we like it or not, economic values will continue to determine the relative worth of technological achievement.

Presented at the Second Mechanical Pulping Conference of the Technical Association of the Pulp and Paper Industry, Poland Spring, Me., Sept. 19, 1955.

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HOW TO BUY RUBBER COVERED ROLLS

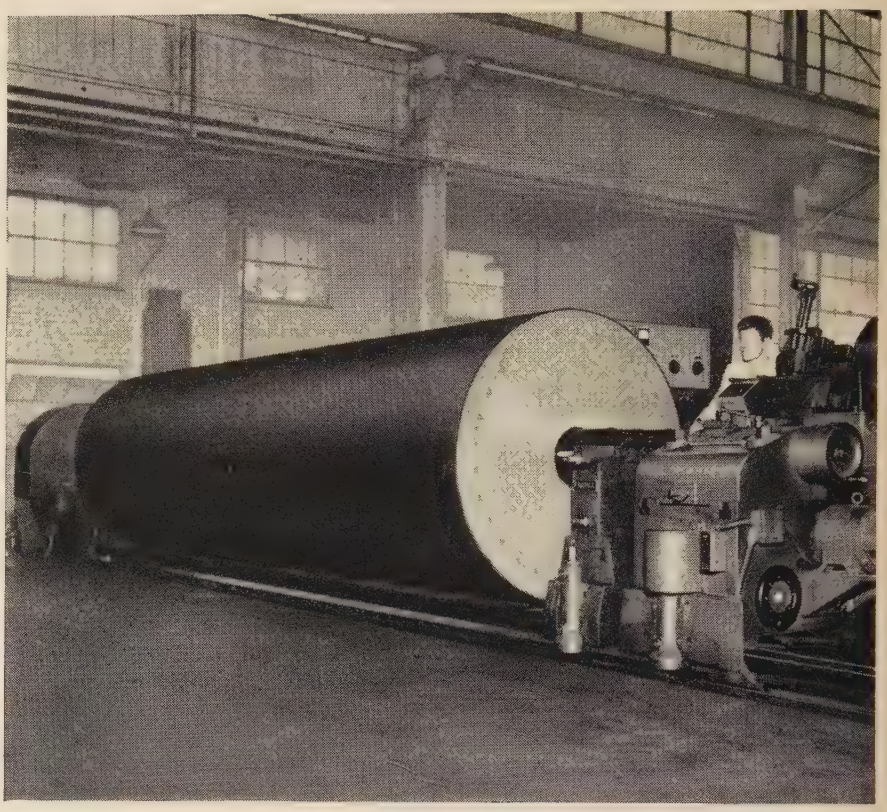
TO MEET SPECIAL ROLL REQUIREMENTS

. . . and get "More Use per Dollar"

Insist on roll covering that is custom-made by roll covering specialists . . . with large, up-to-date equipment and facilities.

Separation of the rubber from the metal core is a primary cause of failure with ordinary rubber covered rolls. Look for a company who has developed a superior rubber to metal bond that prevents cover separation. Make certain the company that handles your roll covering job has the specialized experience and know-how for producing the correct rubber compound for your requirements to prevent cracking, hardening, corrugation and oxidation. Be sure they have the facilities to handle your job regardless of size. Determine whether they have the modern equipment to vulcanize and grind your roll covering to the precise diameter you require . . . to insure uniform and permanent density for your operations.

Specify rubber covered rolls custom-made to meet your specific operating conditions . . . specify Manhattan Rubber Covered Rolls.



Largest grinder and largest roll covered in U. S. Grinder can take rolls 35 ft. x 62" diameter.

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Over 60 years of experience is ready to serve you at Manhattan for the development and production of roll coverings to meet the special needs of your plant. Manhattan roll covering specialists have developed an inseparable bond of rubber to metal core and roll cover compounds that virtually eliminate troubles due to cracking, hardening or corrugating. Modern precision roll grinding and vulcanizing facilities can handle the largest rolls made and insure accuracy of dimension within .002". Custom-made to give you uniform production quality, Manhattan Rubber Covered Rolls assure permanent density and long, trouble-free service under all working conditions. Discuss your job requirements with an R/M roll covering specialist. He'll tell you why Manhattan Rubber Covered Rolls last much longer . . . give you "More Use per Dollar".

RM-518

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MANHATTAN RUBBER DIVISION — PASSAIC, NEW JERSEY

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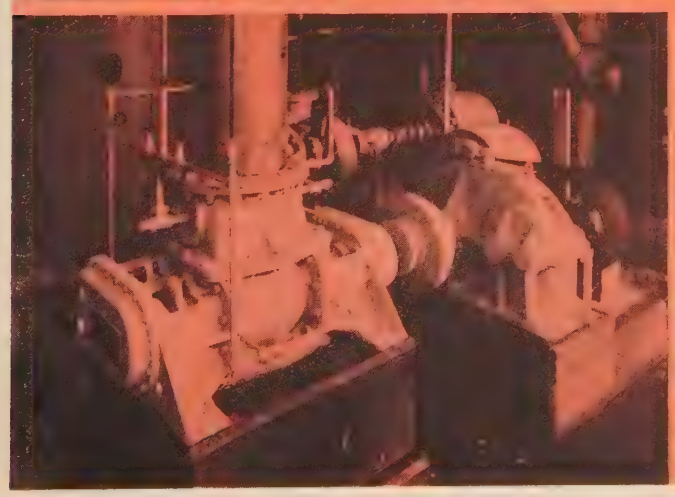

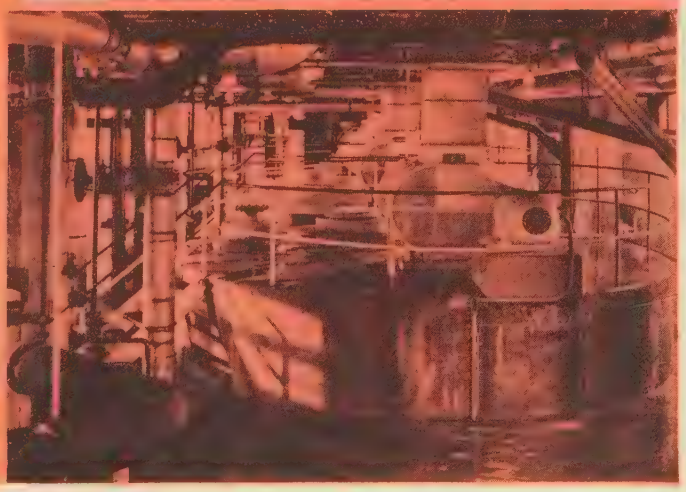

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Three 9'6" × 16' Vacuum Brown Stock Washers
Five 8' × 14' Vacuum Washers
Two 9'6" × 16' Valveless Vacuum Deckers
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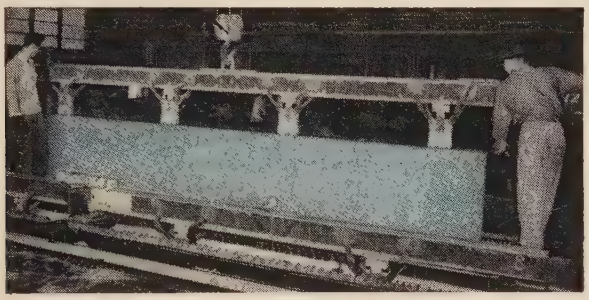
CF&I LECTRO-CLAD Nickel Plated Steel

Guards your product against contamination

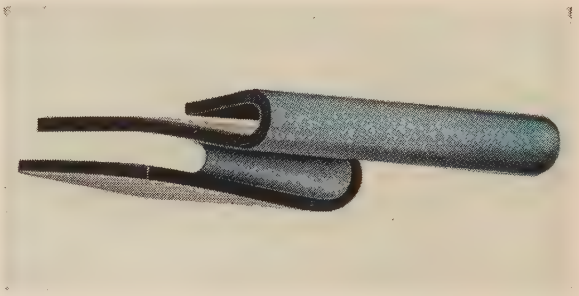
Many product contamination problems are now being solved with CF&I LECTRO-CLAD. This new nickel plated steel is being used in many heavy industrial fabrications, such as tank cars, processing equipment, storage tanks, and many other containers for products that must be kept free of contamination or discoloration.

CF&I LECTRO-CLAD's contamination control properties compare very favorably with rolled nickel-clad steel or solid nickel; LECTRO-CLAD is much better in this respect than many of the protective coatings now used on steel.

These photographs illustrate some of the manufacturing and fabricating techniques used with CF&I LECTRO-CLAD.

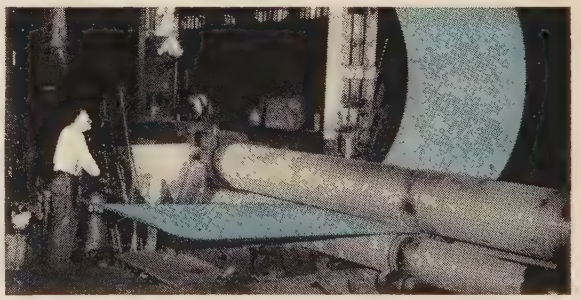


After the steel-backing material has been carefully cleaned and inspected, the nickel plating is applied by the patented Bart Process. This consists of electro-depositing a .006" to .010" coating of pure nickel uniformly over a steel surface.



After plating, the material is subjected to rigorous adhesion flame tests and a 180° bending test (shown here). These tests assure that the nickel bond will not fail even if the material is subsequently worked beyond the failure point of the steel backing itself.

CF&I LECTRO-CLAD provides the only heavy industrial nickel plating that permits fabrication by standard steel shop procedures. Here, manual arc welding is being performed on the nickel side with no damage to the plating.



CF&I LECTRO-CLAD possesses excellent working properties for rolling, forming, flame cutting, shearing and pressbrake operations. No special equipment is needed. Extreme tension or compression during forming will not disturb the nickel bond.

CF&I is now producing LECTRO-CLAD in the form of plates, sheets, pipe, heads and fittings. *For complete details, write for our new Technical Manual on LECTRO-CLAD Nickel Plated Steel.*

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3010

A MAN AND THE PAPER INDUSTRY—HUGH J. CHISHOLM (1847–1912)

HUGH J. CHISHOLM

It is traditional for a company, at some point near its fiftieth anniversary, to relate the past to the present and to its conception of the future. The Oxford Paper Co. soon will enter upon its fifty-fourth year. Emerson's often quoted statement that "An institution is the lengthened shadow of one man" was never truer than in regard to this company. The story of the years of planning and building at Rumford which preceded the founding of Oxford, and of the first crucial years of the company's history—is necessarily the story of Hugh J. Chisholm, Sr.

Because more than four decades have passed since my father's death, I believe I can be reasonably objective. It would be impossible, in any case, to separate the threads of his life from those of the Oxford story, or, indeed, from the history of Rumford.

It is equally true that the continuing and thriving accomplishments of Oxford and of modern Rumford lend perpetual meaning to his life. His business philosophies and attributes of character are ever present in the minds of those of us who follow on the course he so clearly set. As a young man in training I was close to many of his interests and activities and soon became aware that he felt Rumford to be the heart of his achievements, and that the Oxford Paper Co. represented to him both the current essence and the potential of what he dreamed in a field which became his final choice: *papermaking.*

In preparing what is perforce merely an outline of our company's history I have borne in mind the words of Dr. Charles Penrose: "As we look backward let us look forward." I am confident Hugh J. Chisholm would concur in this thought.

Hugh Joseph Chisholm was born at Chippewa, Ont., Canada, on May 2, 1847, the fifth of ten children whose parents were Alexander and Mary Phelan Chisholm. Alexander Chisholm had migrated lately from Strathglass Glen, Scotland, about 15 miles west of Inverness, and had just begun adjustment of his life to the primitive economy of Canada in the 'Forties when he was accidentally and tragically drowned. Young Hugh Chisholm had been attending the local grammer school, but now, at 13, he was thrown upon his own resources.

He met the sudden responsibility of obtaining work in digging potatoes at 25¢ a day. Subsequent events make plain that he was by no means a lazy lad, but 2 days of potato-digging convinced him that the labor of agriculture was not his *forte.* A few days later he had a job selling newspapers and magazines on the sooty red-plush trains running from Detroit to Toronto.

There was another boy about the same age, with the same job on the alternate run. He was Thomas A. Edison and the two became lifelong friends.

One was to move on to great achievements in the realm of invention, the other to wholly new conceptions in the pulp and paper industry. For both the springboard was this apprenticeship in travel and communications. America was developing an enormous appetite for news and information, and beginning to demand both more quickly and from wider sources. The standard of living was rising and America was determined that it should lift even higher.

To serve such ambitions on the part of a youthful and energetic nation, Thomas Edison moved into his destiny via electricity whose expanding possibilities fascinated him. His associate, the young Canadian, felt that distribution of newspapers and magazines on the trains could be handled more efficiently than heretofore, yet with profit, and that in this direction lay his own path toward larger concerns. But before launching into the stream of commerce as a captain rather than one of the crew, the young Chisholm took a precautionary step that was characteristic throughout his life.

No more than a boy in his 'teens, he realized that he lacked experience and education as to basic business principles. Therefore he invested his entire capital—$50.00, and out of earnings, too!—in a commercial night course offered by a Toronto business college.

There he learned fundamentals which he felt now fitted him for his next move, formation of a partnership with one of his brothers, also in his 'teens. They called their new enterprise "Chisholm Brothers" and in a calm and businesslike manner entered into the distribution of newspapers and magazines on the Grand Trunk Railway. In a remarkably short time they acquired the privileges of sales on trains from Chicago to Portland and Halifax, and soon had added the steamboats of the principal lines operating on the St. Lawrence River.

It was not long before these youngsters had won the respect of publishers as well as of the owners of the railroads and ships whose passengers they so ably served. The market they controlled for newspapers and magazines, and later other articles of use to travelers, represented more than 5000 miles of rail and steamship lines. Chisholm Brothers were employing more than 200 boys and young men, many of them considerably older than themselves—and every one uniformed in trainman's cap and coat with the proper brass accoutrements.

To move from the distribution of periodicals to

Hugh J. Chisholm, member of the Newcomen Society, President, Oxford Paper Co., Portland, Me.

For wet strength in a hurry—UFORMITE 700

UFORMITE 700 gives your paper high wet strength fast. In almost any kind of furnish—bleached or unbleached kraft, sulfite, or groundwood—you get high strength right off the machine.

UFORMITE 700 has other important advantages: *Highly efficient*—provides effective results over a wide range of resin-to-pulp ratios. • *Easily mixed*—no acid pretreatment, no special equipment needed. • *Simply controlled pH*—acid, alum, or blends of both can be used. • *Conveniently added*—at any desired point from beater to headbox. • *Long storage life*—the stability of UFORMITE 700 helps eliminate inventory problems.

Other Rohm & Haas chemicals for the paper industry include hydrosulfites for bleaching wood pulp; resin emulsions for paper coating and saturation; surface-active agents, pitch dispersants, deodorants, and bactericides.

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publishing them was, of course, a logical step, even if a long one, and was taken shortly after the formation of Chisholm Brothers in 1867. The two brothers became, in fact, the originators of what was then a new idea in publishing. They specialized in the publication of tourist guides and souvenir books of travel.

The year 1872 was a most eventful one in the life of Hugh J. Chisholm. It was in that year that he bought out the interests of his brother in the New England part of their joint enterprise and relinquished his holdings in the Canadian activities of Chisholm Brothers. It was also in that year that he became a citizen of the United States of America, established residence in Portland, Me., and married Henrietta Mason, daughter of Dr. and Mrs. Edward Mason of that city.

He had seen that his ultimate goal must be toward basic industry. His feeling for Canada as the place of his birth, and his interest in the welfare of the Dominion, never left him. They were reflected steadily in the relationships of his various enterprises as well as in the many friendships he formed with Canadian and Old Country leaders and industrialists. He saw North America as a whole, as a continent made up of men and women whose basic concerns were in common.

But even as a very young man he had perceived that his future lay on this side of the international boundary, that here was where he would work and build. The Dominion was not then, of course, anywhere near its present status in population, markets, capital, or sheer initiative. The States, and specifically the State of Maine, offered far more opportunity in this youth's eager view.

An early associate of my father speaks wonderingly of his ability to understand and encompass a complex subject with seemingly little observation and a minimum of basic data. This represents the kind of mind, I have been told, that needs various matters on which to feed. It is therefore not surprising to find the youthful Chisholm, very soon after taking up residence in Portland, making explorations throughout the State in search of foundations for solid competitive enterprise.

Those magazines and newspapers he had distributed as a boy had become more than publications in his mind. They were, of course, printed on *paper*—literally on hundreds of tons of paper. Now, as a publisher, he found out a good deal about how paper was made—and what it cost—and why it cost what it did.

Then, as now, the manufacture of wood pulp and of paper from that pulp took tremendous quantities of wood, power, and water, and plenty of good men with experience ranging from that of the logger to that of the technician in the mill. It was an industry of dramatic scope, offering an ever-expanding service to the Nation's growing economy and public need.

It was an industry which therefore fascinated Hugh J. Chisholm from the start of his career in Maine. Young Edison had dreamed of the practical potentials of electricity, dreamed of them as he gazed at the mysterious movements of the telegrapher's key. Young Chisholm saw the unbelievable power of wood fibers when made into paper—for news and instruction and for the smooth operation of business and industry in all their broadening phases.

The initial potentials of the Maine forests were, of course, obvious to the first settlers. But those potentials had been limited by the pioneer economy. The problem of the forests was the problem of clearing for agricultural pursuits, and the lumber and wood products industries grew almost as by-products of that clearing of the trees. In those days our American paper industry was still quite new. Indeed, the chemical processes of papermaking from wood fibers had hardly begun at the time this perspicacious young man began selling publications on the trains.

His first awareness of the possibilities in wood pulp became visible when he acquired an early patent for making wood fiber-ware, still an important industry in New England. This was followed by organization of the Somerset Fibre Co. at Fairfield.

He had been working unceasingly since the age of 13 and now, at 25 and with a wife concerned for his health, he was persuaded to take his first vacation. In New Orleans he received a telegram advising that the fiber-ware plant had burned to the ground and urging that he return to Maine at once.

Instead, he completed his holiday. He had to begin all over again in the industry of his choice and that would require more thinking and planning. The start of that could be in New Orleans as easily as in Portland.

Upon his return to Maine, my father's mind revolved more and more around a relatively new concept of pulp and paper. If it were to survive in the modern industrial world it must, he saw, keep pace with industry—and he visualized it steadily as a scientific industry so organized, to match the general and accelerating business march of America.

It was in 1881 that he established the Umbagog Pulp Co. at Livermore Falls, and when that organization was well under way he sold out his remaining interests in the fiber-ware plant. He was now fairly launched on his career of papermaking and via the basic raw material, wood pulp.

The structure of his dream was complete in its broad outline within the young man's mind. The shading and the detail were being filled in gradually. But he was fully aware of the work to be done before the dream could be brought into complete reality. Said William DeWitt Hyde, then president of Bowdoin College, on the occasion of awarding to my father the honorary degree of Master of Arts shortly before the latter's death: "The leading characteristics of Hugh J. Chisholm seem to be a prophetic grasp of future possibilities, and indomitable patience, perserverance, and energy in developing the means of realizing those possibilities."

And so, whenever there was time, he continued his restless exploration of every part of Maine.

The region where Rumford, Me., now stands was little more than a wilderness in the Midwinter of 1882 when Hugh J. Chisholm first saw it. Houses were few and scattered widely. Occasionally, in summer, a few people might be attracted by the tales of the beauty of the Penacook Falls, later known as Rumford Falls. But the railroad ended at Bethel, 24 miles away, and most of the outsiders who had seen this

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Every ounce of Nalco 680 provides active alkaline alumina . . . always available for rapid reaction. That means reduced alum requirements, lower acidity, better sizing, better retention, and therefore, better products.

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KRAFT MILL — Alumina Retention

"Improvement in sizing, better retention of alumina, and general texture of the sheet using Nalco 680 are very marked. Converter reports the sheet handles better."

SULFITE BOND MILL — 45% Less Alum

"Results using Nalco 680 at the rate of 5 pounds per ton have been good. Improved sizing and reduced alum so that 140 pounds of alum is being added per 4500 pounds of furnish, instead of the previous 250 pounds of alum. This enabled the mill to meet rigid pH specifications for the paper."

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stretch of the Androscoggin River were the hardier variety of fishermen and hunters.

Into this lonely scene there drove one winter day in that year of 1882 a horse and sleigh from the direction of Bethel. Bundled in the robe of the rented rig was the subject of this sketch, recently turned 32. He had come neither to hunt nor fish, although the beauty of the Falls was by no means lost on him, as we know from his later account of that historic journey.

He had heard, in Portland and around Livermore Falls, some reports that interested him, if true. He had heard that the Androscoggin, at a point soon after re-entering the State of Maine, takes a sudden turn southeast and thereupon drops nearly 200 ft. in less than a mile.

To my father that meant one thing—tremendous potential power for new industries. He had decided to look for himself and he had seen no good reason to wait for an equable spring in which to do so.

Leaving sleigh and horse at the road, he trudged across the crusted snow and found precarious footing on a table of rock just below the Falls. It was, he often said later, a most magnificent sight. He stood there a very long time, oblivious to the cold and the thunderous sound of the Falls. He had been making a study of what was then a whole new science to most of America—hydroelectric power and the science of hydraulics as applied to industrial use. He realized, in such terms, what he now saw.

Twenty-five years later, his life rich in accomplishments, he recalled clearly the thoughts that ran through his mind when as a youth he saw this vast unharnessed power which had been going to waste for countless generations. He wrote: "The idea of developing and making productive this great unchained power before me and of planting a city in the wilderness was what came to me then."

That this recollection was accurate is shown clearly by the steps which he early took to bring that idea to reality. Those steps were characteristically immediate. But he realized the time and effort involved: "I knew," he wrote, "that the realization of this dream would mean not only the expenditure of much money, but of the most careful and painstaking thought, the most untiring patience and energy. It was not a work to be accomplished in a single night."

Our founder's recollection of the Rumford area in 1882 as a sleeping farming community was likewise accurate. In his mind that condition was sharpened by contrast with the potentials he saw in the Falls on that memorable day.

By virtue of its location and the early more or less primitive water-wheel harnessing of the power, the old town of Rumford had enjoyed a curiously isolated prosperity in the 'Fifties. At the peak of this phase Rumford had a population of 1375. That is not impressive when compared with its more than 14,000 today, but for that corner of the world, in that day, it was rather remarkable.

However, at the time of young Chisholm's visit, events far beyond Rumford had seriously damaged the old ambitions of the town. The call of the Far West with its own virgin timber, its prospect of gold and free land, to say nothing of new freedoms, was particularly strong in the ears of venturesome New Englanders. As populations of towns like Rumford dwindled, shining axes with handles made in Rumford began to ring out in a new wilderness on the slopes of the Rockies and along the Pacific shore. Out on the Willamette River in Oregon was growing up another city of Portland.

And on the heels of that great migration came the tragedy of the Civil War. To this struggle, as it has to all conflicts engaged in by this Nation, the Rumford area sent its young men. And then the potentialities of the whole vicinity were sapped by economic dislocations in the aftermath of war between the States. By 1865, there were abandoned farms along the Androscoggin. In the town itself one business shop after another put up its shutters for the last time. The stacks of its young industries grew cold.

This disintegration went on for 30 years. In that midwinter of 1882 there were less than a thousand people living in the area. Before the power of Rumford Falls could be harnessed and the settlement revived again there would be less than 900.

As he had foreseen, there would have to be a decade of planning and building at Rumford when the founder's plans could be completely realized there. Meanwhile he was not idle, nor did his interest in the pulp and paper industry lag. In 1887 he founded at Livermore Falls the Otis Falls Paper Co., capitalized at three quarters of a million dollars. Hugh J. Chisholm became its treasurer, its general manager, and principal owner. At that time it was one of the largest plants of its kind in North America and later became an important unit in the organization to be known as the International Paper Co.

So devoted did my father later become to Oxford Paper Co., and so indelibly has he left his principles on its aims and policies, that few outside the industry today realize that prior to the founding of Oxford he originated and organized the International Paper Co., in 1898, and became its president in that same year.

International Paper Co. is still the largest and most complex pulp and paper manufacturing organization in the world, operating in both Canada and the United States and making a wide variety of products from both northern and southern species. Some observers of the industry have commented that the advent of International marked the beginning of the modern pulp and paper industry in management and organization as clearly as the first sulphite wood pulp is said to have marked its modern phase technologically.

At the end of the last century pulp and paper stood on the threshold of vastly wider responsibilities to the American economy. Ever greater demands were being made of the industry as an instrument of social usefulness. These basic facts, as we have seen, were very much on my father's mind. From boyhood he had been watching these changes at their very base; he had seen them fomenting and expanding in the great markets for paper.

Newsprint was then the greatest segment of the industry in this Country, particularly in New England and upper New York State. The newsprint industry had not migrated, to the present extent, into Canada. Newsprint from southern pine was as yet unknown. Hugh J. Chisholm knew that careful planning and organization were necessary to the paper industry if

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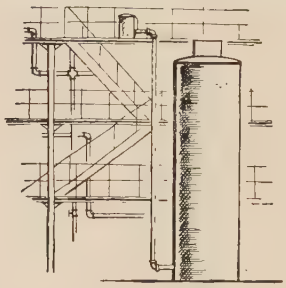

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the challenge of the approaching century was to be met with anything like full strength.

Accordingly, he sought as associates A. N. Burbank and W. A. Russell, and with these two men brought together 20 pulp and paper mills in Maine, Massachusetts, New Hampshire, Vermont, and northern New York.

That is very easily stated, but this audience will appreciate what a Herculean task of organization and planning for distribution of products was involved. The bulk of production represented by these mills was, of course, newsprint; and they were producing about 60% of the newsprint used in this Country.

The strain of that task and the energy required for it are possibly reflected in the death of Mr. Russell who succumbed on July 27, 1898, less than 5 months after succeeding to the presidency Mr. Burbank, who had resigned on January 31 of that year.

Hugh J. Chisholm, then first vice-president, became acting president until August 24 when he was voted unanimously into the presidency by the board of the new company. He was president of International from that date until Oct. 30, 1907, when he resigned to become chairman of the board.

It was on Nov. 27, 1909, that he resigned all duties with International to become in the following year president of Oxford Paper Co.

On the occasion of its own fiftieth anniversary, the International Paper Co. paid official respects to the founding mills and to its one-time president's concept in bringing the various managements together, referring to it as "a period of transition from the traditional papermaking of the early newsprint mills to the modern era."

That bridge from the old to the new conception of pulp and paper manufacturing was precisely what Mr. Chisholm wanted to erect in those earlier days of "IP" reaching for a broader base on which to operate.

A somewhat amusing characterization of my father in the formative years of International was written to me not long ago by one of their vice-presidents. He recalled. "I have heard all sorts of stories about your father, some true and some incorrect. I knew him better than I have known any other president of this company. He was indeed a dynamo. He would run out to Chicago quite frequently and sometimes would decide that I must return to New York with him at once. Without even a bag or tooth brush, I'd find myself picking up what I needed on the way to the train."

Today the great International Paper Co. operates 20 mills in the southern and northern United States and in Canada. It is a $450,000,000 company producing 4,000,000 tons of pulp, paper, and board products annually. Those products create total sales of over $600,000,000 a year.

Like those who came to the management of International Paper Co. later and were to develop it into the fine institution it is today, this experienced and imaginative papermaker soon began to think in terms beyond newsprint.

He had seen the Falls at Rumford and had been visualizing paper production there. He was to become instrumental in the building of the Rumford Falls Paper Co., using the power of the Falls; and this newsprint mill became a part of the original International combine and was in later years converted to pulping operations for Oxford.

Now, as a vital part of the plan he dreamed for Rumford, he envisioned a papermaking plant of a very particular kind. It would devote itself to papers for magazines, book publishers, modern printing establishments, and to an ever broadening and changing market represented by American business and industry in general.

And it would be known as Oxford Paper Co. because its site would certainly be at Rumford which lies in Oxford County in the State of Maine.

The 10 years of patient and painstaking negotiations, involving literally hundreds of small parcels of land around the Falls at Rumford, were at length completed. Then, with 1400 acres which assured the use of the Falls and adjacent water rights, the organization of the Rumford Falls Power Co. was undertaken in 1890. This was the nucleus from which the new city of Rumford was to grow.

President Chisholm's frequent presence in Rumford in those days were concerned chiefly with the planning, as he later said, "for the best utilization of the power." He had observed that probably the highest efficiency of the Falls was not to be obtained by setting manufactories along the river side, but by a system of canals. Forthwith he had made a plaster cast of the whole area—it may still be seen in the lobby of the power company offices at Rumford—and on this he planned where the canals should go, pasting on the cast strips of tissue paper to indicate the exact locations.

About this phase of his activities, Judge Putnam of the United States District Court of Portland once said: "Apparently proper account is not taken publicly of the fact that Hugh J. Chisholm possessed and exercised wonderful mechanical, engineering, and constructive genius. It was especially in hydraulics, one of the most difficult and perplexing sciences of the day, that he excelled."

The availability of 52,000 new horsepower would be of little meaning at Rumford without transportation facilities and in these it was still sadly lacking in 1890.

With characteristic directness combined with his ever-present patience and determination, Hugh Chisholm had been working on the problem. In the year that the power company was organized he gained control of the nearly defunct Rumford Falls and Buckfield Railway. This line he extended from Gilbertville to Rumford, a distance of 17 miles. Reorganizing the line under the name of the Portland and Rumford Falls Railway he then extended it from Mechanic Falls, where it met the Grand Trunk Railway, to Rumford Junction in the town of Auburn where it connected with the Maine Central Railroad. Now Rumford had *two* connections with points east and west where formerly it had none.

Five years later, in 1895, this man of vision organized the Rumford Falls and Rangely Lakes Railroad Co. This line extended from Rumford to Bemis on Rangely Lakes and was primarily for transportation of wood. In 1907, the properties of both roads were leased to the Maine Central and subsequently were sold outright to that company.

The Oxford Paper Co. was formally organized at a

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meeting in the Falmouth Hotel at Portland, on Dec. 7, 1899. My father's dream of a paper mill that would be integrated in the fullest sense was now beginning to take tangible shape.

The first board of directors of Oxford was a most interesting cross section of the interest of New England. Indeed, for that day, it was a cross section of the basic commercial enterprises of the whole Country.

Hugh J. Chisholm at this time was, as we know, president of International Paper Company. Whitney P. Cox was president of A. F. Cox and Sons, shoe manufacturers; Ami Whitney, owner of Kendall and Whitney, distributed agricultural machinery and supplies throughout the Northeast; Charles W. Gardner was a promoter of industrial enterprises with wide experience in manufacturing fields; Fred E. Richards was head of Union Mutual Life Insurance Co.; A. N. Burbank was a member of the board of International Paper Co.; John E. Burnham headed Burnham-Morrill, food canners; Jonathan Bulkley was president of Bulkley Dunton and Co., then as now a leading international paper merchant organization; and Waldo Pettingill was a farmer, teacher, and civil engineer and an official of the new Rumford Falls Power Co. They were Maine men with the exception of one Bostonian and two from New York City.

The capitalization was for half a million dollars, all subscribed. By-laws were adopted at this first meeting, and next day the Attorney-General of the State of Maine certified the organization. A week later the board instructed Mr. Pettingill and Mr. Gardner to start plans for the mill at Rumford.

On December 19, a contract was drawn up with Tower and Wallace which provided that this firm supervise the erection of a two-machine mill together with a soda pulp mill which would have a daily capacity of 30 tons. In addition there was to be a sulphite pulping operation of 20 tons a day.

The following spring the work at Rumford was well along. Meanwhile our founder was busy studying the publishing market and although the mill was not completed until October of 1901 it was decided, on Sept. 6, 1900, to increase the capacity to four, instead of two, paper machines, and to purchase additional soda and sulphite pulping digesters, together with the necessary equipment for the operation of an additional unit.

Soon after this vote for expansion, taking place a year before completion of the mill, Oxford negotiated with the government to supply all post cards sold through the post offices. It was then the most valuable contract in the whole book paper trade.

The first "cook" of soda pulp occurred on Nov. 9, 1901, and the operation of sulphite pulping began 8 days later. Oxford's first shipment of paper was consigned to Bulkley, Dunton and Co. in New York City, 2 days after it rolled from the machines on Nov. 19, 1901.

The Oxford Paper Co. was off to an auspicious start, but the first few years were not all easy sailing. There needed to be almost constant improvement and plant enlargement. Consequently the demand for capital was great and continuous. Hugh Chisholm was still devoting vital attention to International Paper Co., but Frank E. Tufts, an early treasurer of the Oxford Paper Co. has left a revealing footnote as to the availability of Mr. Chisholm when Oxford stood in trouble.

Describing an oft-repeated scene, Mr. Tufts wrote a few months before his death in 1933: "Hugh J. Chisholm never failed to show splendid courage in backing his conviction and intention that Oxford must stand at the front in the production of fine book papers."

When Hugh J. Chisholm resigned from International and, in 1910, took over the presidency of Oxford the latter had made remarkable capital progress, had expanded several times, and its usefulness and service were well established in the exacting markets it had set for itself.

In that first full year of the new president's leadership it began to show a profit. Through all the years since, including two world wars and two major depressions, Oxford has continued to show a profit.

Hugh J. Chisholm died on July 8, 1912, at the age of 66.

He had lived to see an assured future for the town of Rumford, which he had created out of the wilderness of 1882, and for the Oxford Paper Co. on which he had come to focus his keenest interest in his later years. At the time of his death, Oxford had already grown from a two-machine mill to one running eight paper machines and was producing 63,000 tons of pulp and 44,000 tons of paper annually.

And Rumford, the sleeping farm community this keen-visioned pioneer had resolved to bring into new life, had become what it is today: a model manufacturing community, unique in the annals of industrial cities.

It seemed to me then, and it seems to me now almost half a century later, that in planning the new Rumford my father had in mind the theme voiced by a speaker at the dedication of the Mechanics Institute which he caused to be built there in 1911 for the use of mill employees.

I refer to the phrase: "Industry is for man, not man for industry."

The thought and planning which gave rise to that phrase, also enabled the president of Bowdoin College to say of him that "with all his vision and energy he combined a deep sense of responsibility for the beneficent use of his powers and resources, and a kindly and generous interest in the welfare of those who through their labors were associated with him in his enterprises."

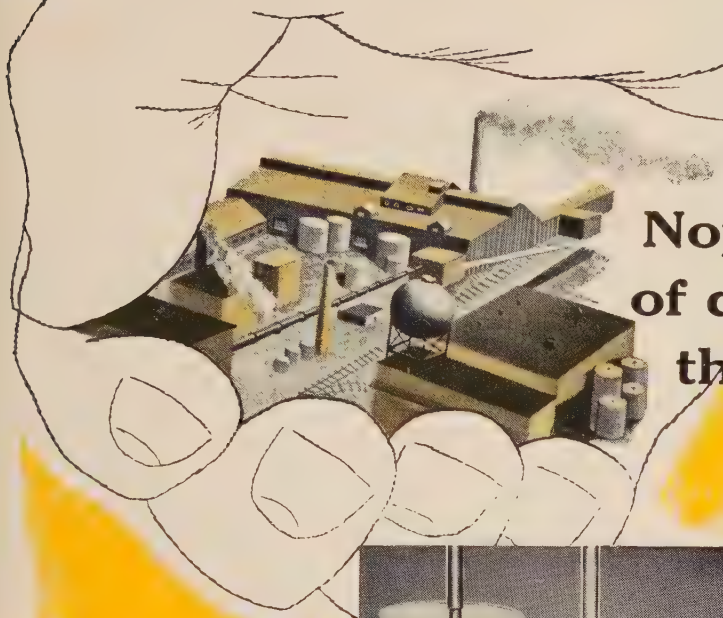
Inevitable changes have taken place in Oxford during the 40 years since Mr. Chishom's death. I am deeply confident that he would have approved them, for all have been based on the conviction and determination which the company has inherited—namely, that Oxford shall stand in the front in the production of fine book papers.

One of the major changes has been the extension of our manufacturing interests into the Miami Valley of Ohio, where paper has been manufactured for many, many years. In 1927, Oxford purchased control of the Miami Paper Co. at West Carrollton, Ohio. Now a wholly-owned subsidiary, it is known as the Oxford Miami Paper Co.

Its history antedates that of Oxford. Paper was first made there from straw, in 1871. Soon after that, both straw and rag papers were made; then, as time went on, the use of wood pulp was introduced.

Both West Carrollton and Rumford have seen vast changes take place in the pulp and paper industry and

Why do we bring your mill into our laboratory?



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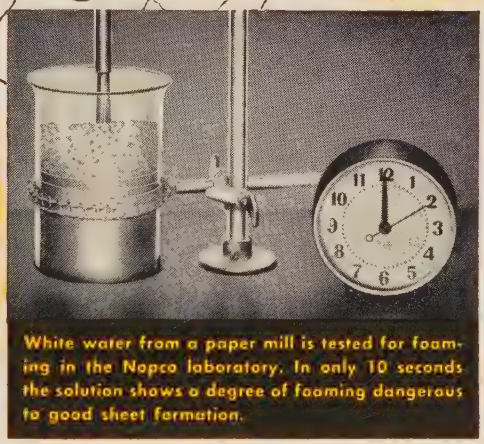
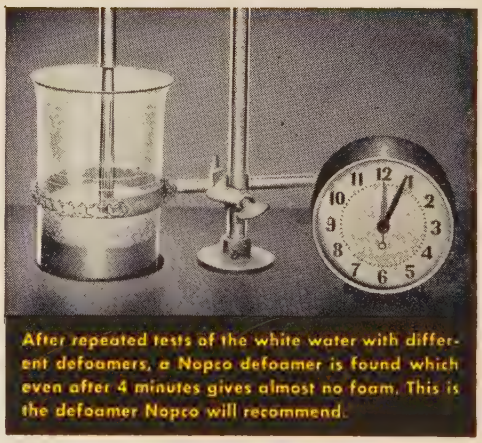


White water from a paper mill is tested for foaming in the Nopco laboratory. In only 10 seconds the solution shows a degree of foaming dangerous to good sheet formation.



After repeated tests of the white water with different defoamers, a Nopco defoamer is found which even after 4 minutes gives almost no foam. This is the defoamer Nopco will recommend.

Nopco well knows that an excellent defoamer in one paper mill may be an indifferent performer in another. Since our aim is always to reduce foaming to the minimum under any conditions, we have set up testing techniques which in effect "bring your mill into our laboratory."

We do this by testing samples of white water from your mill, with every potentially effective defoamer—including if you like, the one you are now using. When we have finished these exhaustive and accurate tests, we *are able to determine scientifically* which defoamer will give *your* mill the best fibre distribution, fewer breaks, higher machine speeds, and improved sheet formation that is your due.

Nopco, the very first to make a chemical defoamer for the pulp and paper industries, has an unrivalled wealth of first-hand experience—and the widest variety of defoamers, both paste and liquid. Why not *make sure* you have the best possible defoamer, by consulting Nopco today?

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are justly proud of a company tradition which has contributed its part to many of the most important of those changes.

Pulp and paper now represent the sixth industry in the United States. In the viewpoint of modern economists they are even more important than this rank would indicate. In both world wars they have been classified essential by the government, just as have steel and copper and similar basic products. The per capita consumption of paper today in the United States is almost 400 lb. for every man, woman, and child in the Country. That is virtually double the per capita consumption of 1926. And parallel with population growths, new uses for paper are being discovered and successfully marketed almost every day.

Today, pulp and paper are exactly what Hugh J. Chisholm foresaw they would become at the turn of the century: a very scientific industry, so organized and so arranged technically to keep pace at all times with the vast and complex economy it serves.

Now—as the Oxford Paper Co. enters its fifty-fourth year—it is one of the Nation's largest producers of book paper, currently accounting for about 8% of the total output and operating the world's largest book paper manufacturing plant under one roof.

Today, the combined daily output at Rumford and West Carrollton makes an interesting comparison with the daily capacity contemplated by the founders of Oxford in 1899. They planned on 44 tons, which was of course a sizable daily output then. Now the combined Oxford production is 750 tons of paper a day, roughly enough to fill 38 freight cars. The Rumford facilities, which create 80% of the production, now include 13 paper machines.

A moment ago I referred to the fact that Oxford is a fully integrated operation. I meant that this integrated manufacturing reaches from forests to finished product quite literally. It includes not only adequate production of wood pulp, but also water and power. It embraces not only the procurement and utilization of wood species abundantly growing in Maine, but the manufacture of some of our chemicals as well.

And, while Oxford is well past the half century mark, it remains as vigorously progressive as the founder and his associates intended. Only recently, Oxford completed a postwar capital investment amounting to nearly 20 million dollars. Historically a solid company, Oxford has reset its financing in preparation for the more competitive period which may lie ahead for all business and industry.

The nature of the pulp and paper industry is such that the average American family rarely is aware who makes its paper—even though it may use more than half a ton of it each year.

But the makers of many quality products preferred by the American family—the builders of great magazines, the publishers of distinguished books, the packagers of good foods, the makers of products that are household words, the converters of paper to a thousand and one uses for business and industry, and the men who carry on the fine and gentle art of printing—these people know the Oxford Paper Co.

This Newcomen Address, dealing with the life and work of Hugh J. Chisholm (1847–1912) and with the history of Oxford Paper Co., was delivered at the "1952 Maine Luncheon" of The Newcomen Society of England, held at Hotel Lafayette, in Portland, Me., U.S.A., when Mr. Chisholm was the guest of honor, on Dec. 12, 1952.

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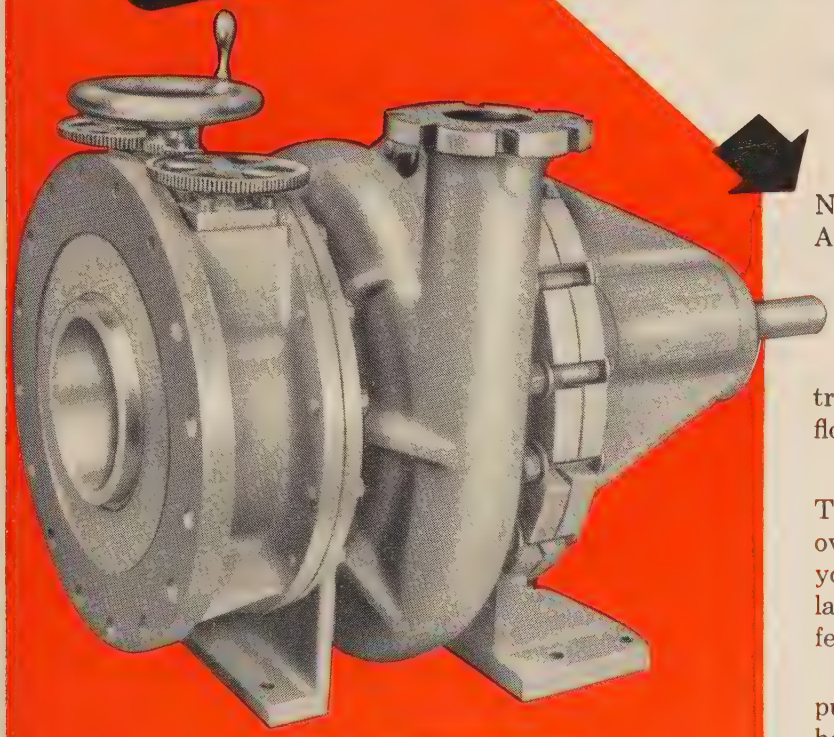

No need to regulate pump speed using Allis-Chalmers new proportioning pump.

Key to this revolutionary *ACAP* pump is an internal bypass mechanism — bolted on the inlet of a single-suction pump. Bypass mechanism can be controlled automatically or manually to reduce flow of stock when needed.

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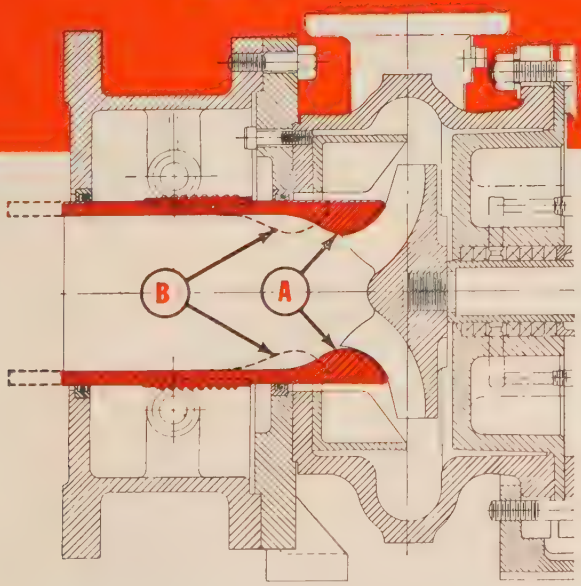
This pump gives positive, accurate control over paper stock delivery. It also permits you to maintain constant agitated recirculation for blending purposes without affecting uniform delivery of stock.

Get complete details on the new *ACAP* pumps for proportioning, fan service or head box supply. Contact your nearby district office or write Allis-Chalmers, Milwaukee 1, Wisconsin.



ACAP is an Allis-Chalmers trademark.

- ***Operates at any point on the curve***
- ***No Valves to clog or clean***

Adjustment of the actuating mechanism slides the bypass cylinder toward or away from the impeller. The clearance between pump end of the cylinder and the impeller determines the amount of stock recirculation — regulates the flow at the discharge nozzle.

At Position *A* (see diagram) outlet flow is at maximum, recirculation slight; at Position *B*, outlet flow is minimum, recirculation is maximum.

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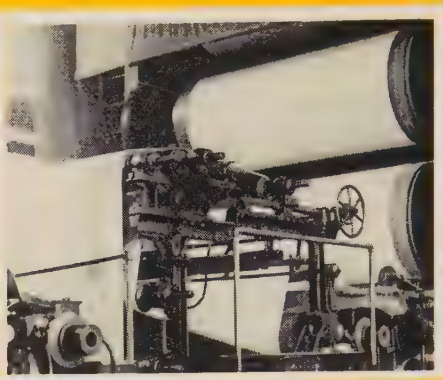

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1. Your caustic soda freight rate.
2. Your facilities for handling caustic.
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Advantages of 73% liquid

1. With 73%, there is a substantial saving in freight charges. 63% less water is shipped per unit weight of dry caustic soda.
2. You will place fewer orders. This cuts down on your billing work.

Disadvantages of 73% liquid

1. It is priced $2.00 more per ton (dry basis) than 50% because of higher manufacturing costs.
2. If you store it as 73% liquid, you will need heated, nickel-clad steel storage tanks.
3. If you dilute 73% to 50% while unloading, you will need a cooler and other equipment. This represents a considerable investment which can be reduced if you have suitable equipment already on hand.

Use this table to see if you can save with 73%

Use the table at right to find your approximate saving on freight charges with 73% liquid caustic. The table balances two cost factors . . . lower freight charges and the higher initial price of 73% liquid caustic.

To estimate your yearly savings, multiply the figure in the right-hand column which applies to you by your annual consumption in tons (dry basis).

From these savings you will have to deduct the cost of equipment for diluting to 50% while unloading.

Freight rate per hundred weight in cents (including taxes)	*Net savings per ton (dry basis) in dollars*
5	minus 1.40
10	minus .80
15	minus .10
16	0
20	.60
25	1.20
30	1.80
35	2.40
40	3.00
45	3.70

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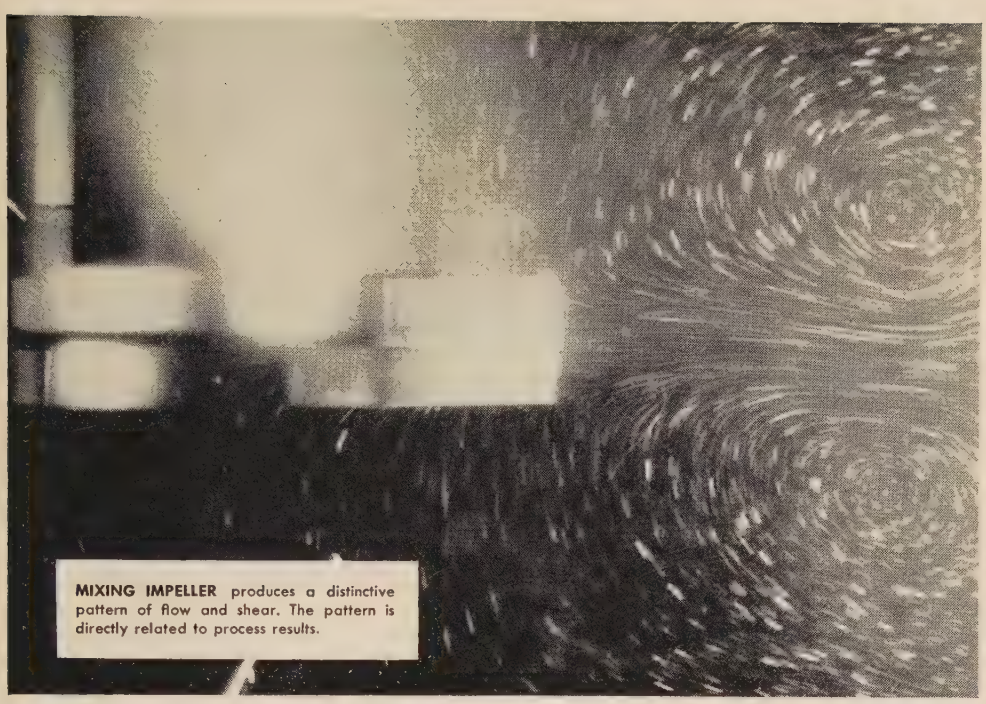

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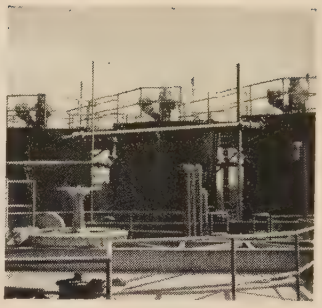

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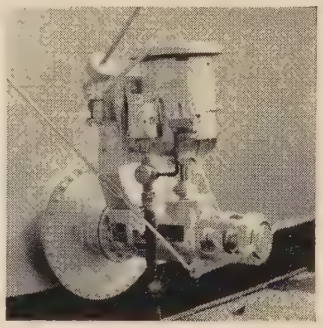

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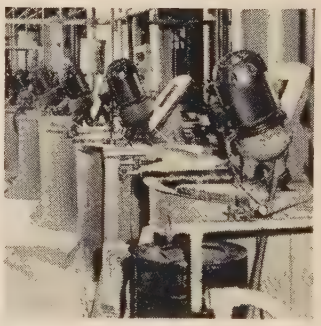

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The Operation of Paper-Products Machines*

Occupational Hazards to Young Workers

SHELDON W. HOMAN

THE Fair Labor Standards Act of 1938, as amended, in addition to its basic minimum wage and overtime provisions which apply to all workers, contains special provisions relating to child labor. These provisions establish a minimum age of 16 years for general employment, and an 18-year minimum age for such occupations as the Secretary of Labor shall find and declare to be particularly hazardous for minors of 16 and 17 years of age, or detrimental to their health or well-being. Findings and declarations by the Secretary of Labor are based on investigations made by the Bureau of Labor Standards and are in the form of "Hazardous-Occupations Orders," which are issued after public hearings have been held on them. The effect of such orders is to raise the minimum age for employment to 18 years in the occupations they declare hazardous.

This report presents the findings of an investigation of the hazards to minors in operating a group of power-driven machines used in the converted paper-products industry. These machines are used to convert paper into other products such as packaging materials, containers, stationery, and the like. The purpose of the investigation is to determine which of these paper-products machine operations is sufficiently hazardous to warrant application to them of the 18-year employment minimum.

Occupations involved in the operation of paper-products machines were selected for study because some of these machines are known to cause serious injury. Moreover, a considerable number of 16 and 17-year-old boys and girls are believed to be employed in industries using paper-products machines. It is estimated that in 1950 between 5000 and 6000 minors under 18 years of age were employed in establishments manufacturing converted pulp and paper products.† An unknown, though probably substantial, proportion of these minors were undoubtedly engaged in work on or in connection with paper-products machines. In addition, minors under 18 years of age are employed on paper-products machines used in many other industries.

That young people under 18 years of age are engaged in work on paper-products machines is also evidenced by statistics and case histories of injuries to minors working on such machines. Examples of accident cases coming to the attention of the Bureau of Labor Standards are given below.

1. A 17-year-old boy was working on a band saw in a paper box factory. As he turned around, he caught his right arm in the blade, and his hand was cut off at the wrist.

2. A boy of 16, a helper in a factory manufacturing paper products, accidentally caught a finger in a die press. He suffered 40% permanent-partial disability of the finger.

3. A 17-year-old stock boy in a paper-products plant caught his fingers in the gears of a tube-cutting machine. He lost 10% of the use of his ring finger.

4. A 17-year-old girl, working as a machine operator in a paper bag plant, tried to clean the cutting bar on a bag-maker while the machine was running. She suffered a severe injury to her index finger.

In one State, North Carolina, according to workmen's compensation statistics, 18 minors under 18 years of age were reported injured on paper-products machines during the 3-year period July, 1947 through June, 1950‡.

METHOD AND SCOPE OF STUDY

In this study, investigators drew information from a number of sources. Plants were visited in a number of States where converted paper products are manufactured. Machine hazards were studied under different operating conditions and their danger discussed with plant safety personnel. Statistical evidence of the hazards of the machines was obtained when available. State child-labor laws and regulations were analyzed to see what restrictions they set on the operation of such machines by minors under 18 years of age. Safety engineers employed by trade associations or manufacturing companies were consulted during the course of the investigation and careful consideration was given to the opinions of all persons interviewed.

This investigation covered the hazards of work associated with the operation of machines used to remanufacture paper or pulp into an end product whether or not such machines were operated in establishments primarily engaged in manufacturing paper or pulp products. In this report, such machines will be termed "paper-products machines."

Paper-products machines are chiefly to be found in plants that remanufacture or convert paper or pulp into a finished product. Some of the identical machines, however, are used in establishments which are primarily engaged in other types of business. For example, guillotine paper cutters are used in many industries, even nonmanufacturing industries, where sheet paper is cut to a smaller size. And the same kind of printing press

SHELDON W. HOMAN, Division of Safety Standards, Bureau of Labor Standards, U. S. Department of Labor, Washington, D. C.

* This report (United States Department of Labor Bulletin No. 181) of the hazards to 16- and 17-year-old workers in operating power-driven paper-products machines served as the factual basis for Hazardous-Occupations Order No. 12 issued Aug. 6, 1954, and effective Sept. 11, 1954. The order declares as particularly hazardous the operation of certain machines used in the paper-products industries; and in effect establishes an age minimum of 18 years for employment in operating the machines.

†Estimated by the Bureau of Labor Standards from unpublished data furnished by the Bureau of Old Age and Survivors Insurance, and average employment figures published by the Bureau of Employment Security.

‡ North Carolina Industrial Commission: Tenth and Eleventh Biennial Reports.

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may be used in a job printing shop as in a factory making set-up or folding paper boxes. The scope of this investigation includes such machines wherever they are found. Conversely, machines which are not paper-products machines are not included in the scope of this investigation even though they are operated in a paper-products plant. For example, a milling machine used in the making of dies would not be within the scope of this investigation.

The widest variety of paper-products machines is to be found, of course, in the converted paper-products industry. This investigation, therefore, has concentrated on the study of the kinds of paper-products machines used in that industry. The specific industries classed as paper-products manufacturing in the Standard Industrial Classification Manual, are the following:

Paper Coating and Glazing. Establishments primarily engaged in manufacturing coated and glazed paper from purchased paper. Important products of this industry include coated-book, waxed, and gummed paper (including gummed labels, and paper and cloth tape) waterproofed wrapping paper, fly paper, and cloth-lined paper.

Envelopes. Establishments primarily engaged in manufacturing envelopes of any description from purchased paper.

Paper Bags. Establishments primarily engaged in manufacturing paper bags from purchased paper and similar materials. Important products of this industry include kraft paper bags for groceries, shipping or heavy-duty paper bags or sacks for cement, flour, coal, etc., and glassine bags, cellophane bags, and miscellaneous merchandise bags.

Paperboard Boxes: Folded, Setup, and Corrugated. Establishments primarily engaged in manufacturing paperboard containers or boxes from purchased paperboard or fiber stock. Important products of this industry include folding paper boxes; setup boxes; corrugated solid fiberboard boxes; decorated, lithographed, lacquered, and fancy covered paperboard boxes; cigarette and confectionery boxes.

Fiber Cans, Tubes, Drums, and Similar Products. Establishments primarily engaged in manufacturing fiber cans, cones, cores, mailing cases, ribbon-blocks, spools, tubes, drums, and similar products with or without metal ends.

Die-Cut Paper and Paperboard and Cardboard. Establishments primarily engaged in die-cutting purchased paper and paperboard, and in manufacturing cardboard by laminating, lining, and surface-coating paperboard. Important products of this industry include paper bottle caps and tops; index, jacquard, library and other cut cards; cut-outs; photograph folders, mats, and mounts; stencil cards for addressing machines; and cardboard panels and pasted chipboard and newsboard.

Wallpaper. Establishments primarily engaged in designing, printing, and embossing paper for interior walls and ceilings.

Pulp Goods, Pressed and Molded. Establishments primarily engaged in manufacturing all kinds of pressed and molded pulp goods, such as pulp plates and utensils, and papier-mâché articles other than statuary and art goods.

Converted Paper Products Not Elsewhere Classified. Establishments primarily engaged in manufacturing from purchased paper, miscellaneous converted paper products not elsewhere classified, such as stationery, papeteries, crepe paper and crepe paper products, paper napkins, doilies, and towels, playing cards, drinking straws, printed and unprinted paper patterns, egg-case fillers, laminated building boards and papers, cups, plates, and utensils, toilet paper, confetti, and paper novelties.

The Standard Industrial Classification Manual from which these manufacturing groups are taken, refers to "purchased paper" meaning that the plant does not manufacturing its own paper. For the purpose of this report, whether the manufacturer of the paper product produces or buys paper is of no importance. And, as previously stated, the report is intended to cover the use of paper-products machines wherever such machines are used.

KINDS OF OCCUPATIONS AND MACHINES CONSIDERED IN THIS INVESTIGATION

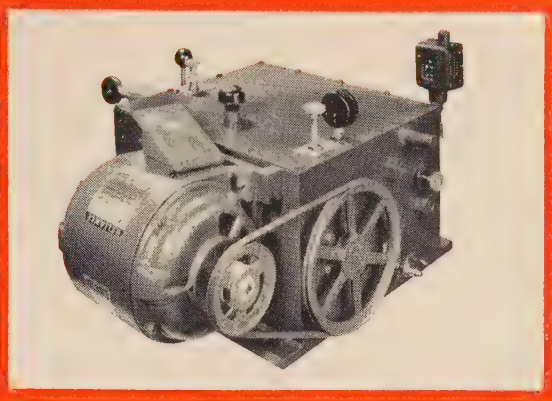
The kinds of occupations covered in this investigation are those involving work on or in connection with power-driven machines used in manufacturing a product from paper or paper pulp. And as previously stated, such machines are covered whenever they are operated, whether in a plant devoted entirely to the manufacture of converted paper or pulp products, or in a plant that is primarily engaged in some other type of business.

Conversely, the investigation is not concerned with non-machine operations, such as hand stripping or box blanks or work in the shipping department of a corrugated box plant. Also, the investigation does not cover any of the operations entering into actual manufacture of pulp and paper from wood or rags.

There are literally hundreds of different types or kinds of machines used in the converted paper-products industry. Many of these are special machines designed to perform a specific operation The machine is used for no other purpose and would not be found in another segment of the industry. Other machines are of a general nature; they might be found in any branch of the paper-products industry or, indeed, in other industries.

While there are many kinds and types of paper products machines, they follow a general pattern insofar as their function is concerned. A list of the principal types of machines by function or by the type of product they produce is as follows:

Bag machine, bag-making machine
Bottoming machine (bags)
Box-making machine (collapsible boxes)
Bundling machine
Calender roll and plating machines
Clasp machine, eyelet machine
Counting, stacking, and ejecting machine
Corner cutter
Corner stayer
Corrugating machine
Corrugating and single and double facing machines
Covering, lining, or wrapping machines (setup boxes)
Creping machine
Cut-off machine
Dornbusch machine (Wallpaper)
Ending machine (setup boxes)
Envelope machine
Folding machine
Gluing, sealing, or gumming machine
Guillotine cutter
Hole punching, drilling, or rotary perforating machines
Interfolding machine
Jogging machine



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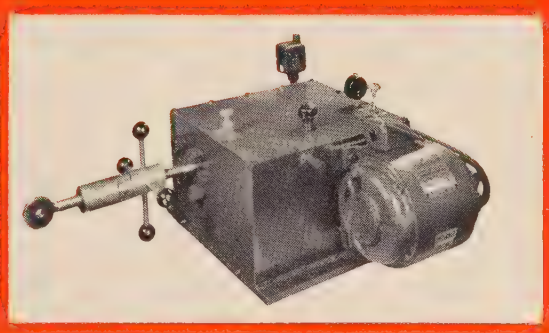

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Tube cutting machine
Tube winder
Tube machine (paper bags)
Window patch machine
Wire stapling or stitching machine
Wire or tag stringing machine

The foregoing names are in most cases, the names of machines by function. In some cases these are individual machines; in others they are a unit of a combination machine which performs more than one function. In the mass production of paper products several functions are usually combined in a single machine; thus a machine may perform the functions of scoring, folding, and gluing. Various combinations of functions are incorporated in the production types of machines, depending upon the kind of product and the quantity to be manufactured. Usually, the greater the quantity (the longer the run) the more fully automatic the machine, and the more functions are performed by the machine.

Like machines are not always given the same names in different branches of the industry. What is ordinarily referred to as a guillotine cutter in most branches is sometimes known as a "straight knife" in other branches. Machines are sometimes named after the product they produce, rather than their basic function. Thus a "pin-ticket" or "shipping-tag" machine is in reality a form of punch press. It is difficult, therefore, to list all machines by whatever name under which they may be known.

Defining the machines in terms of the industry where they are used is also difficult. For example, a machine that does gluing, folding, and sealing of folding paper boxes is usually referred to as a gluing machine, while one that performs a somewhat similar operation on corrugated boxes may be known as an automatic folding and sticking machine. It is almost impossible, therefore, to assess the hazards of various machines by the process involved because of the different combination of processes that are possible, and because the hazards of the process vary with the difference in product. For example, the hazard of slotting may vary considerably between heavy fiber or corrugated stock and light paperboard, not only because of the difference in stock but because the process, and even the type of machine, may be different. And a process that may be very hazardous when performed alone on a single machine may be quite different as to hazard when performed as a part of a continuous process. In the first case the material would probably be hand fed into a manually operated machine, while in the latter the material would be fed automatically into a continuously operating machine. For example, cutting paper stock on a guillotine cutter is much more hazarous than the cutting-off of stock as the final operation of a corrugating and double facer machine. Or, hand feeding a platen die-cutting press or a plunger-type die-cutting press is a much more dangerous operation than die-cutting on a cylinder press where the stock is carried under the die by an automatic feed.

In view of these facts, the hazards of the various machines used in the paper-products industry could not be measured on a straight process basis; the evaluation was made instead on the operation of the individual machine, whether that machine performed a single function or a combination of functions. The operation of all machines was studied in the course of this investigation; those considered the most hazardous are further discussed in the section The Machines and Their Hazards.

INJURY RATES OF THE PAPER-PRODUCTS INDUSTRY

As background for consideration of the hazards of individual paper-products machines, it will be helpful to explore the relative injury rates for the different kinds of paper-products manufacturing plants, based on statistics compiled by the Bureau of Labor Statistics.

The average injury rates for paper-products manufacturing industries are not high when compared with the corresponding rates for manufacturing industries as a whole. These averages conceal both the relative safety of many jobs in these industries and the hazard of others. As has already been stated, the purpose of this investigation is to identify the jobs involving machine operation that are of such high hazard that they should be declared particularly hazardous for minors under the Fair Labor Standards Act and subject to the 18-year minimum age.

The Bureau of Labor Statistics has published injury statistics for the year 1951 for three segments of the industry—envelopes, paperboard containers and boxes, and miscellaneous paper and allied products. Table I is based on such data.

Table I

Industry	*Frequency rate, all disabling injuries*[a]	*Frequency rate, serious injuries*[a]	*Average days lost or charged per case*	*Severity rate*
All manufacturing industries	15.5	0.8	82	1.3
Paper-products manufacturing:				
Envelopes	16.3	0.7	33	0.5
Paperboard containers and boxes	18.1	1.0	64	1.3
Miscellaneous paper and allied products	13.7	0.8	75	1.2

[a] Compiled by Bureau of Labor Standards from Bureau of Labor Statistics Bulletin No. 1137, Work Injuries in the United States During 1951. The frequency rate for all injuries is the average number of disabling work injuries for each million employee-hours worked; this will sometimes be referred to as the "general frequency rate." The frequency rate for serious injuries is the average number of serious injuries (resulting in death or in permanent-total or permanent partial disability) for each million employee-hours worked. The severity rate is the average number of days lost as a result of disabling work injuries for each 1000 employee-hours worked. A disabling work injury is one resulting in death, in any degree of permanent impairment, or in the loss of at least 1 day's time on any day other than that on which the injury occurred.

According to these figures, plants manufacturing paperboard containers and boxes have a somewhat

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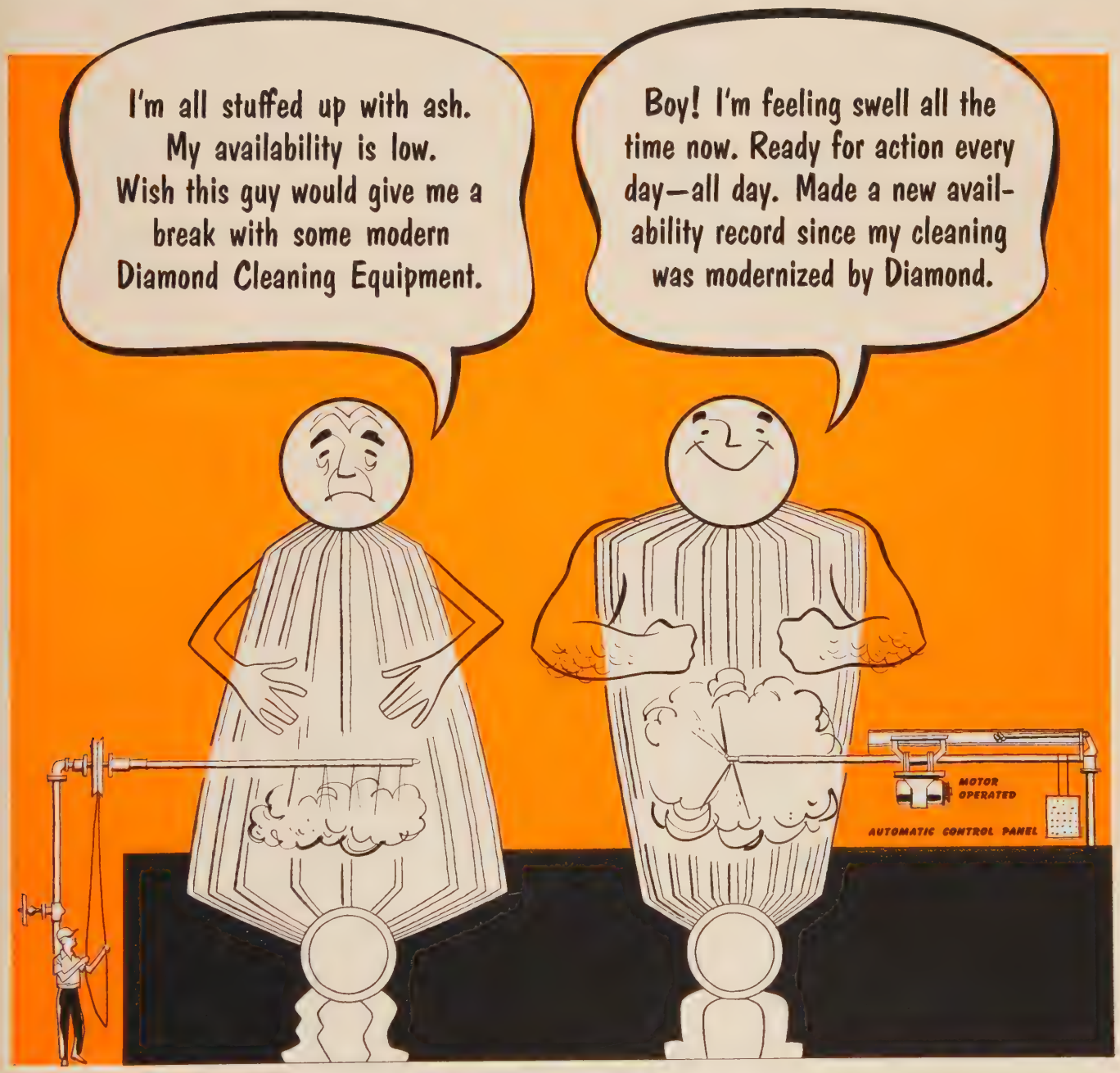
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higher general frequency rate than have all manufacturing industries as a whole, and also a somewhat higher frequency of serious injuries—that is, injuries resulting in death or in some degree of permanent impairment. The severity rate is about the same as that for all manufacturing industries. As measured by the number of days charged per disabling injury, the average severity of injury appears not to have been so great in any of these three paper-products classifications as in manufacturing industries as a whole.

More detailed information on injury rates is available for paperboard-container plants from a special survey made by the Bureau of Labor Statistics for the year 1950.[§] The survey shows that some types of plants manufacturing paperboard containers have more numerous or more severe types of injuries than the average manufacturing plant or the average paperboard-container plant. Table II shows a comparison of rates for each of these industries and for all manufacturing industries as a whole, for the year 1950.

Here it is seen that the paperboard-container plants as a whole have a higher general frequency rate, as well as a higher frequency rate of serious injuries, than all manufacturing industries combined. The relatively high general frequency rate (17.9) is accounted for in large part by the production operations in plants manufacturing corrugated and fiber boxes—27.4 as compared with 14.7 for all operations in all manufacturing industries. The same industry has a somewhat higher than average frequency rate of serious injuries for production operations—1.0 as compared with 0.8 for all manufacturing industries; but the plants manufacturing fiber cans, tubes, and drums have the highest frequency rates of serious injuries, both in production operations (2.8) and in service operations (9.4). The severity rate for fiber cans, tubes, and drums is also very high—4.9 in production operations, 12.0 in service operations. For all manufacturing industries combined, the 1950 severity rate was 1.2.

Available statistics are inconclusive in showing just what kinds of paper-products machines cause the most frequent or most severe injuries in any of the paper-products industries. For this reason, dependence must be placed chiefly on nonstatistical sources of information regarding the hazards of these machines, supplemented by such data as are available. Statistics are useful, however, in showing the importance of machine-caused injuries. Of a total of 1505 disabling injuries reported in the 1950 survey, 359 or 23.9% were due to machines.

§ Bureau of Labor Statistics Bulletin No. 1139, "Injuries and Accident Causes in the Manufacture of Paperboard Containers." No injury-frequency or severity rates have been computed for classifications in which the number of employee-hours was less than 500,000 nor is the average time loss shown when the total number of disabling injuries was under 50.

Table II. Industrial-Injury Rates for Paperboard-Container Plants, According to Type of Plant: United States, 1950

Operation	All manufacturing 1950	All paperboard container plants[a]	Plants manufacturing—Corrugated and fiber boxes	Plants manufacturing—Fiber cans, tubes, drums	Plants manufacturing—Folding boxes	Plants manufacturing—Set-up boxes
Total Operations						
Frequency rates:						
All disabling injuries	14.7	17.9	23.0	16.5	16.7	12.9
Serious injuries[b]	0.8	1.2	0.9	5.1	0.9	1.1
Average days lost or charged per disabling injury	84	85	67	289	69	76
Severity rate	1.2	1.5	1.5	4.8	1.2	1.0
Production Operations						
Frequency rates:						
All disabling injuries	...	18.2	27.4	17.0	15.7	12.8
Serious injuries[b]	...	1.0	1.0	2.8	0.8	1.2
Average days lost or charged per disabling injury	...	57	51	[c]	64	54
Severity rate	...	1.0	1.4	4.9	1.0	0.7
Service Operations						
Frequency rates:						
All disabling injuries	...	14.6	18.0	19.5	9.8	12.9
Serious injuries[b]	...	1.0	0.4	9.4	0.6	0.3
Average days lost or charged per disabling injury	...	89	56	[c]	38	30
Severity rate	...	1.3	1.0	12.0	0.4	0.4

[a] Includes figures not shown separately because of insufficient data.
[b] "Serious" injuries = the sum of injuries resulting in death or in any degree of permanent impairment.
[c] Not computed because of insufficient data.
Source: Compiled from published and unpublished data of the Bureau of Labor Statistics Monthly Labor Review, December, 1951, Vol. 73, No. 6, p. 677, "Paperboard-Container Industry Work-Injury Rates, 1938–50"; Bulletin No. 1098, "Work Injuries in the United States, 1950," Table A; Special Survey unpublished tables 1–5.

THE MACHINES AND THEIR HAZARDS

In determining the machines most likely to cause injury, one or more of a number of factors were considered. These factors were: (1) the inherent hazard occasioned by the design of the machine and the degree to which the hazard is eliminated or lessened by methods of feeding and guarding; (2) opinions of persons consulted during the investigation; (3) observations of the investigator; and (4) substantiating evidence of hazard from statistical data, where available. Weighing these factors when applied to all machines used in the paper-products industries, the following are the ones most likely to cause an injury, or to cause an injury which is serious in nature.

- Scrap paper baler
- Guillotine paper cutter or shear
- Platen die-cutting press
- Platen printing press
- Horizontal bar scorer
- Vertical slotter
- Wire stitcher or stapler
- Sheeting machine
- Circular or band saw (partition saw)
- Envelope die-cutting press
- Punch press
- Corner cutter or mitering machine
- Corrugating and single- or double-facing machine
- Laminating or combining machine

A discussion of these machines and their hazards, along with methods of feeding and guarding, follows:

Scrap-Paper Baler

A scrap-paper baler is a machine for compressing scrap paper into a bale, and for fastening the bale together with a wire or metal strap. A paper baler is found in all paper-products plants. The very nature of paper-products manufacturing involves a lot of scrap—cutting to size, cut-out or blanked-out sections which are unusable, imperfect blanks, etc.—which is baled and returned to the paper mills as scrap paper. In large plants the scrap paper is usually collected at the machine where the scrap is formed and carried to the baler by means of a system of air or suction ducts. In other plants the paper is gathered up by hand and trucked to the paper baler.

Where a suction collection system is used, and sometimes where hand collection is the practice, the scrap

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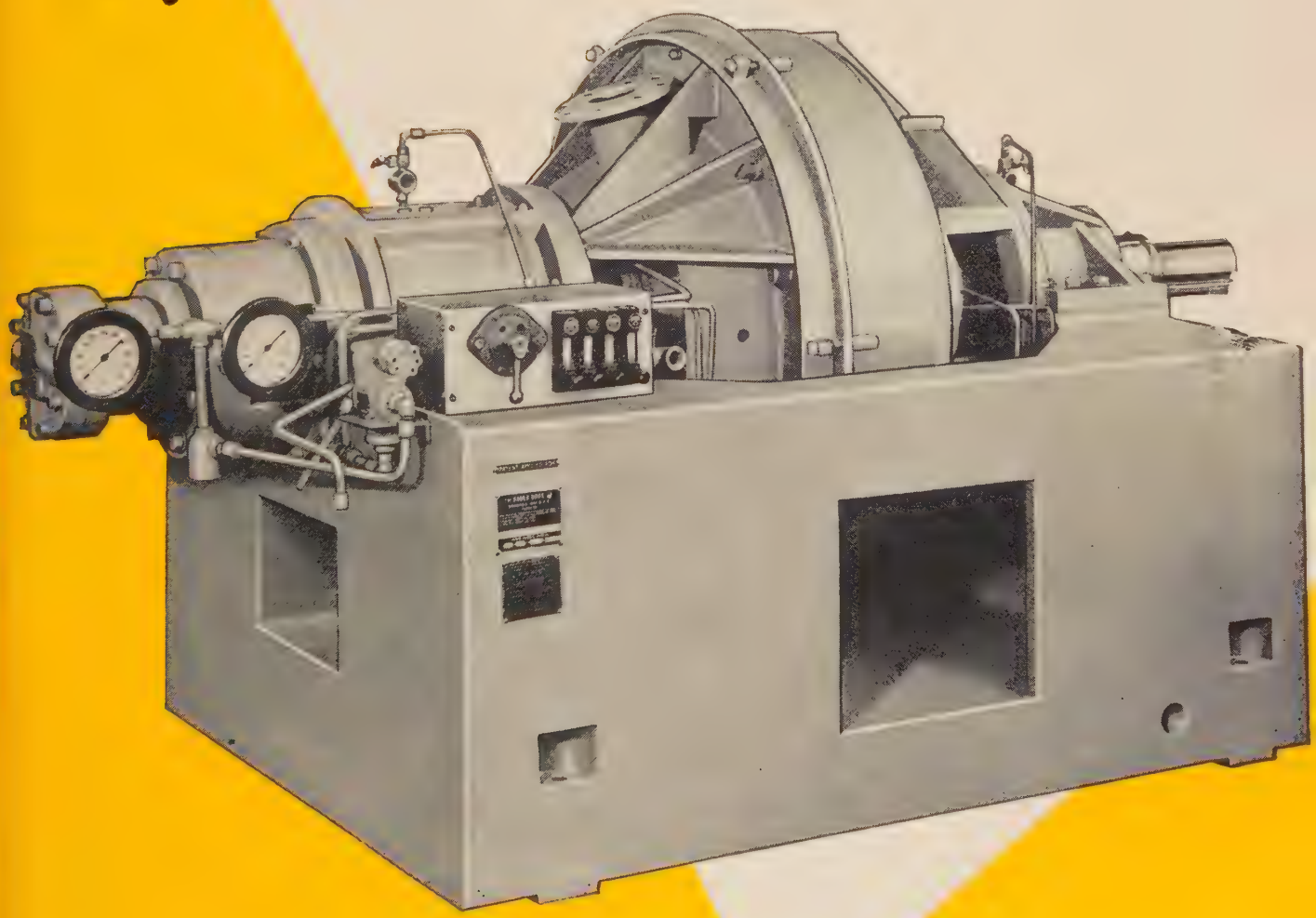

paper is deposited in a bin above the baler and falls by gravity into the baler. Some balers are hand-fed, the paper being thrown into the baler an arm-load at a time, loading being from the top or a side near the top. On some balers the loading opening is entirely open; in others a hinged panel opens when the machine is being loaded, the panel being closed when the paper is being baled.

The baler is simply a large rectangular box, set on end. A power-driven plunger descends and compresses the paper into a tight mass. It is then secured by steel straps or wire. When the bale is completed the sides of the box are opened, the bale removed, and after the sides are closed it is again ready for operation. In some balers a power-driven tamper partially compresses the bale before the plunger completes the compression process.

One hazard of the baler is that of being caught by the descending plunger. Where the paper falls into the baler from an overhead bin this danger is remote. Where the baler is hand-fed, it would be possible for a person's arm to be caught by the descending plunger should someone else operate the control mechanism while paper was being manually placed in the baler. An accident such as this would cause a severe injury, probably loss of an arm.

A more probable cause of injury would be in removing the heavy bales of paper. Bales weigh anywhere from 300 to 1000 lb. They are bulky and awkward to handle. They are pushed and pulled out of the baler, sometimes on rollers set in the floor. This involves hard physical work, and strains and sprains are not uncommon. Work about the baler is particularly difficult and dangerous to a young person who has not reached physical maturity. One person usually operates the baler, although the work may be done by a crew of two or three persons.

No statistical data are available which will aid in determining the degree of hazard of the scrap baler. But in view of the possibility of being caught in the baler, as well as the heaviness of the work, operation of the paper baler is too dangerous for young persons.

Guillotine Paper Cutter or Shear

The guillotine cutter, or straight knife, is potentially one of the most hazardous machines found anywhere. It is a very simple machine, consisting of a heavy knife blade set at a slight angle from the bed of the machine, and held in place by an overhead framework. Paper to be cut is placed on the bed of the machine, the line of cut being directly under the knife. When operated, the knife descends shearing through the paper.

It may be operated in a number of ways. Some old machines simply have a foot treadle and tramping on the treadle releases the brake, throws in the clutch and the knife descends. Other old machines substitute a hand lever for a foot treadle. These afford practically no protection to the operator.

Most modern machines are equipped with a two-handed tripping device which requires the simultaneous use of both hands to operate the machine. The tripping device may consist of two electric switches in series, both of which must be closed before power can be applied. The two-handled tripping device may be a mechanical interlock on the clutch but its purpose is the same—to keep the hands of the operator away from the danger zone.

In theory, two-handed control should make guillotine cutters foolproof. Unfortunately, it does not. Some two-handed controls, particularly home-made ones, can be made inoperative by tying down or plugging one control using only the other. On some machines controls can be operated by simply applying pressure on a button or lever and if the button or lever is located near enough to the knife, the operator could press the control with his elbow leaving his hand free to get under the knife.

Another weakness of many two-handed tripping devices is that they are usually designed for one person to operate but two or more persons may actually assist in the operation. For example, the stock being cut may be too heavy for one man to handle, so two men lift the stock onto the bed of the machine and center it under the cutter. Each operator then presses his control button or lever but his other hand is free. He may be caught when trying to adjust the stock being cut. It is, of course, possible to equip a machine with a variety of controls to take care of any possible combination of operators or helpers. Actually this is seldom if ever done because the amount of cutting would not warrant it. A guillotine cutter is primarily a standby machine, used for occasional cutting of paper stock in sheets to size. If production were such that the machine was in constant operation, an automatic machine of some kind would probably be used. There is also the possibility, however remote, that poor adjustment or a mechanical failure of clutch or brake might allow a guillotine paper cutter to operate when the hands of the operator were under the knife.

Injury rates for cutting operations in paperboard-container plants are available from the 1950 special survey mady by the Bureau of Labor Statistics. These rates indicate that departments performing cutting operations in the paperboard-container industry tend to have frequent and serious injuries, in comparison with the average for all manufacturing industries combined. Table III shows this comparison for the year 1950.

Table III

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Severity rate*
All manufacturing industries	14.7	0.8	1.2
Cutting operations:			
All paperboard-container plants	22.5	1.7	1.6
Corrugated and fiber box plants	28.4	0.9	0.5
Folding-box plants	16.9	1.1	1.0
Setup box plants	29.1	4.3	4.5

Not all of the injuries occurring in cutting operation departments are due to machines performing cutting functions. But since injuries due to cutting machines are included among those occurring in departments performing cutting operations, the injury rates for cutting operations are worth studying.

Cutting operations in each of the categories of paperboard-container manufacturing for which such rates are available had a higher general frequency rate than the

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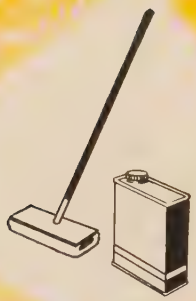
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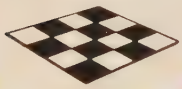
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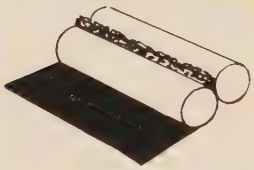
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average for all manufacturing industries. The frequency rate of serious injuries was also higher than the average for all manufacturing industries—in most cases considerably higher. The average severity of injury occurring in cutting operations, as measured by the severity rate, varied among the paperboard-container classifications. For all these plants combined, it was slightly higher than the average severity rate for manufacturing industries; for setup box plants it was much higher; for corrugated and fiber-box plants and for folding-box plants it was lower than the severity rate for the average manufacturing industry.

This cannot be interpreted to mean that these high rates were necessarily due to accidents on guillotine shears. Other cutting machines undoubtedly contributed to the high rates, but it does indicate that cutting machines are injury producers and the guillotine shear is recognized as one of the most dangerous of all cutting machines.

Accidents at the point-of-operation of a guillotine cutter are always serious, never minor. When sufficient power is available to cut through a ream or more of paper, hands and fingers offer no obstacle. Because of the possibility of injury, and because the injuries are severe ones, the operation of a guillotine paper cutter should be classed as particularly hazardous for minors.

Platen Die-Cutting Press

Die presses are used for die-cutting, cutting-out, embossing, creasing, slotting or the like. A die is used to cut the paper or paperboard stock into the desired shape. The machine may be either hand fed or automatically fed, and may be of the plunger type (punch press), the platen type, or the cylindrical type. Many paper products are die-cut on a platen press, die-cutting being frequently the first operation that enters into a finished product. Thus, boxboard blanks or paper-container blanks may be cut out on a platen press. Such a press is also used for making various paperboard novelties, such as advertising displays.

The die is locked up in the steel frame called the chase, and the chase is mounted on the press. The die consists of steel "rulers" held in place by wood or cork strips or blocks. The paper to be cut is placed on the platen—a flat piece of metal hinged at the back which swings up against the chase. The pressure between the chase and platen is sufficient to cut through the paper with the impression of the die.

Platen die presses are continuous in operation, the feeding or placing of the paper on the platen being done when the platen is in a lowered position after the previously cut stock has been removed. Most platen presses are equipped with a platen guard which is none too effective. The platen guard consists of a wire rectangular section, the center of which is filled in with canvas. As the press operates and the platen begins to rise, the platen guard rises ahead of it pushing the hand or arm of the operator away before it is caught between the platen and the chase. But a platen guard is not a perfect guard. Seldom does the platen guard extend more than about 4 in. above the platen and it is possible to reach over or around the guard and still be caught between the platen and the chase, or the guard and the chase.

Some presses are automatically fed and danger to the operator is therefore eliminated. Feeding is usually by means of a suction or vacuum disk, the disk picking up the stock and depositing it on the platen, another disk removing the stock after the press has operated. Where automatic feeding is employed, the operator does not actually operate or feed the press—he simply keeps the feeding mechanism of a number of presses filled. The feeding attachment is often not an integral part of the press so that the same press can be fed either automatically or manually.

Depending upon the kind of product manufactured and the production methods used, platen die-cutting presses may be located in one or more of several different departments. In some paper-products plants, die press might be classed as a cutting function, in some other type of plant it might be considered as a slotting or scoring function. Because of this, statistical data are not available to measure the extent to which die-cutting presses contribute to injury rates. There are likewise no injury statistics based on feeding methods.

Injuries due to platen die-cutting presses are likely to be severe—a crushed hand or arm. Presses operate quite fast and manual dexterity is needed to feed them. They may be operated without guards of any kind in which case the possibility of injury is much more prevalent. Considering all these facts, the hand feeding of platen die-presses represents a hazard so severe that its operation should be classed as particularly hazardous and hence closed to minors under 18 years of age.

Platen Printing Press

Like die-cutting presses, printing presses may be either cylinder or platen type, and may be either automatically or manually fed. In method of operation, the platen printing press and the platen die-cutting press are identical. Type is locked into the chase instead of a die, an ink roller applies fresh ink after each impression but otherwise the operation is the same. And since the hazards are created by the method of operation it follows that the hazards of printing with a platen press are the same as die-cutting on a platen press.

In the 1950 Bureau of Labor Statistics special survey of injuries in the paperboard-container industry, work injury rates are available for printing operations. Table IV is a comparison of these rates with those for all manufacturing industries combined.

Table IV

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Average days lost or charged per case*	*Severity rate*
All manufacturing industries	14.7	0.8	84	1.2
Printing operations:				
All paperboard-container plants	22.7	1.4	83	1.9
Corrugated and fiber box plants	32.3	1.6	48	1.6
Folding-box plants	18.0	1.6	111	2.0
Setup box plants	16.7	...	[a]	0.5

[a] Average time loss not computed because of insufficient data.

Except in setup box plants, printing operations in the manufacture of paperboard containers showed a considerably higher general frequency rate, a higher severity rate, and a much higher frequency of serious

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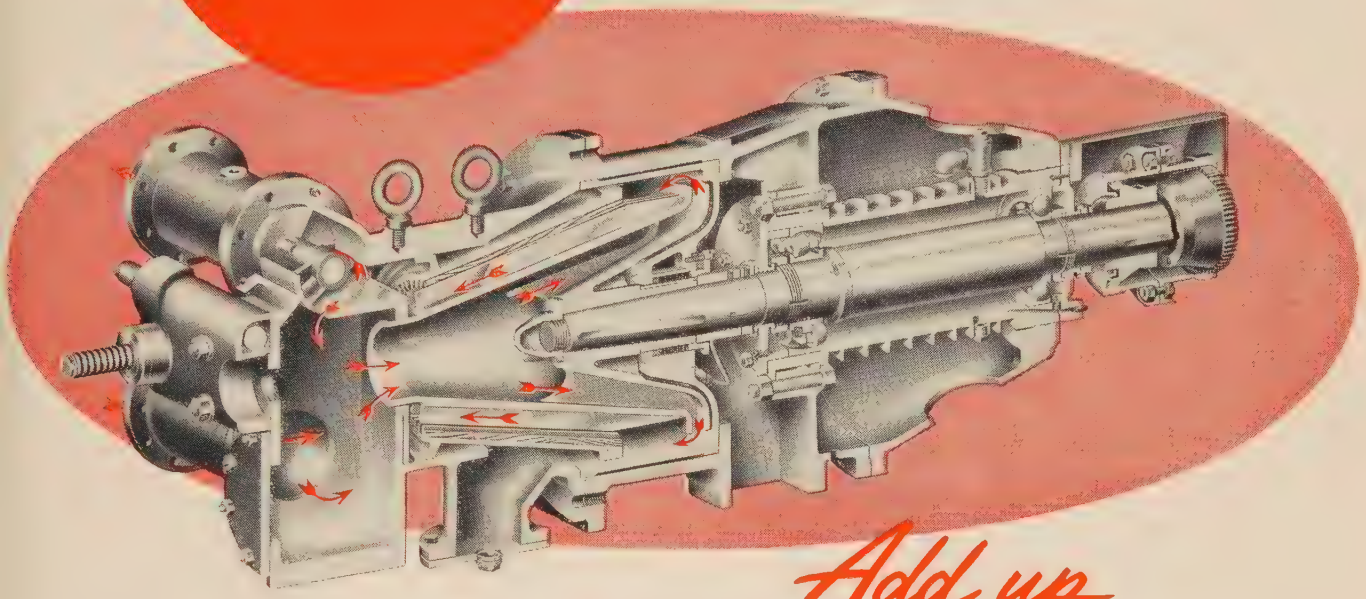

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injuries, than did all manufacturing industries combined.

Not only are the injury rates relatively high for printing operations in paperboard-container plants, but the number of injuries caused by printing presses in such plants is larger than those caused by any other type of machine in the same industry. Of the total of 1505 disabling injuries reported for the industry, 359 or 23.9%, were caused by machines. Of these 359 machine injuries, 70 or 19.5% were caused by printing presses, and 9 of them (nearly 13%) involved amputations.‖

How much platen printing presses contribute to the frequency or severity of injuries in printing operations or on printing presses, is not shown in the 1950 special survey of the paperboard-container industry. Other data are available, however, which indicate that platen printing presses, regardless of the industry in which they are used, cause injuries of higher average severity than those caused by machines in general.

According to Illinois workmen's compensation statistics, based on compensable cases closed during the cumulative two-year period 1951 and 1952, the average number of days lost or charged per case was 292 days for platen printing presses, in comparison with 255 days for all machines. (These averages are based on the experience of all industries combined and are not restricted to the paperboard-container industry.)¶

But, as previously pointed out, the findings of this investigation are based on paper-products machines wherever operated, so that platen printing presses in a printing shop would be considered in the same category as like machines in a paper-products plant.

It is the opinion of those consulted during the course of this investigation that hand-fed platen presses are much more hazardous than automatically fed platen presses. Cylinder presses are considered much less hazardous because, unlike platen presses, feeding does not take place at the point-of-operation. In a cylinder press the paper is carried to the point of operation by a belt or web.

Since platen printing presses operate in the same manner as platen die presses, and since their hazards are the same, like conclusions should apply; namely, that hand feeding of platen printing presses should be declared particularly hazardous for operation by minors.

Horizontal Bar Scorer

Scoring is the process or function of cutting part-way through paper box blanks, boxboard, or fiber stock, along lines where the paper will be folded when made into boxes. The scoring may be done by a revolving circular disk which scores the paper as it is carried through the machine. Scoring may also be performed by a die as the stock passes through a cylindrical press, or in the case of a horizontal bar scorer (up-and-down scorer) by a metal die which moves vertically somewhat like a guillotine cutter.

The horizontal bar scorer is used for scoring heavy fiber stock used in making cartons. It is not used on corrugated paper or light box paper stock. The horizontal bar scorer operates in exactly the same manner as a metal brake. A metal die is supported by a frame raised above the level of the table. Fiber to be scored is placed on the table manually, one sheet at a time. The press is operated by a foot treadle, a single stroke of the press being applied for each score to be made on fiberstock. The die cuts the fiber part-way through.

Horizontal bar scorers are used to a much lesser extent than other scoring methods, and injuries caused by them would not influence the injury rates for scoring operations. There are, therefore, no injury statistical data to aid in determining the relative degree of hazard of bar scoring machines.

Horizontal bar scorers can be guarded by a stationary guard in front of the die. The fiber stock is always relatively thin and the guard can, therefore, be placed close enough to the table so that the fingers of the operator cannot reach under the die. Since this machine scores but does not cut through the stock, there is no necessity for anyone to work at the rear of the machine. But a guard is not universally used, and it is most likely that the scorer will be operated without a guard. When this occurs the machine can be very dangerous. The stock is placed under the die by hand, and if narrow pieces are being scored, the hands of the operator are close to the die zone. Momentary lack of attention, poor coordination, or accidental tripping of the foot treadle may cause the die to descend when the operator's fingers or hands were under the die with likely result of an amputation of the hands or fingers. Characteristics necessary to operate this machine safely without a guard—muscular coordination, alertness, and constant attention—are often lacking in young people. Since this is the case, the horizontal bar scorer should not be operated by minors under 18 years of age. The revolving circular disk-scoring machine is considered much less hazardous than the bar-scoring machine.

Vertical Slotter

Slotting is the function of cutting-out slots from paperboard stock. Slotting machines may employ the principle of a rotating knife (rotary slotter), of the cylinder press using a slotting die, or the principle of the guillotine shear (vertical slotter). Rotary and cylinder press slotters are often units of a machine that performs other functions such as creasing or printing. They are considered much less hazardous than the vertical slotter which is an independently operated machine.

The vertical slotter employs the same principle as the guillotine shear or paper cutter except that a slotting die is used instead of a knife edge. The machine is manually fed from the front, the operator placing the fiber stock on the bed of the machine and operating the control mechanism. The slotter is single acting, that is, it completes a single stroke when the control mechanism is operated. Operation may be by means of a foot treadle, hand lever, or a two-handed tripping device, the latter being the exception rather than the rule.

The hazards are the same as the guillotine shear. If a two-handed trip is not used, the operator can very easily reach under the die. When a two-handed trip is

‖ Compiled by the Bureau of Labor Standards from Bulletin No. 1139, "Injuries and Accident Causes in the Manufacture of Paperboard Containers," United States Department of Labor, Bureau of Labor Statistics, Table VIII, p. 40.

¶ Computed by the Bureau of Labor Standards from the following reports of the Illinois Department of Labor: Annual Report on Compensable Work Injuries, Part II, Compensation Cases Closed during 1952, Table 26, p. A-29; Annual Report on Industrial Accidents, 1951, Part II, Table 27, p. A-31.

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used, it is relatively safe for one operator but when two or more operators or helpers are employed, the purpose of the two-handed trip is defeated unless the controls are so arranged that each operator must use both hands to operate his control mechanism. The die may not extend across the entire width of the machine, as in the case of a shear, but where cutting takes place the die is sharp and sufficient pressure is developed to sever a finger or hand.

A variation of the vertical slotter described above is another type known as the eccentric slotter. The slotting units are mounted on an eccentric shaft which causes them to move in an arc, thus generating a shearing motion. Eccentric slotters are often equipped with a corner cutter located at one side of the machine; the corner cutter is operated vertically, and can be used either in conjunction with or independent of the eccentric slotter. The machine operates continuously, the operator feeding the stock under the dies without stopping the machine.

Injury rates for slotting operations are available from the 1950 special survey of paperboard-container plants, for corrugated and fiber box plants, and for all paperboard-container plants combined. The rates are given in Table V.

Table V

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Severity rate*
All manufacturing industries	14.7	0.8	1.2
Slotting operations:			
All paperboard-container plants	17.2	1.0	0.5
Corrugated and fiber box plants	21.1	1.2	0.6

The general frequency rate, and the frequency rate for serious injuries which in this case consists of permanent partial disabilities, are higher for slotting operations than the corresponding rates for manufacturing industries as a whole, but the severity rate is considerably lower, reflecting the absence of fatal injuries. These data, however, throw little light on the relative hazard of slotting operations. They give no clue to the hazards of the vertical slotter. The vertical slotter is a little-used machine, most slotting operations being performed on a production-type machine. But, since vertical slotting is considered more hazardous than rotary or cylinder press slotting, it is reasonable to assume that the injury-frequency rate, and also the frequency rate of serious injuries, would be at least as high as, and probably higher than, the rate for all slotting combined.

Since the method of operation and hazards are similar to those of the guillotine shear used for paper cutting, the same conclusion applies; namely, that the operation of the vertical slotter should be considered as particularly hazardous for minors.

Wire Stitcher or Stapler

Many paper products, particularly fiber or corrugated paperboard-containers, are held together by round or flat wires driven through the flaps and clinched over. Wire stitching is usually done direct from a roll of wire although pre-formed wire staples may be used.

There are two principal types of machines, the arm type and the automatic stapling machine. In the arm type the box or carton is manually held over the arm of the stitcher and the stitching mechanism operated by a foot treadle. The machine may be single-action, one stitch or staple being driven each time the treadle is tripped, or it may operate continuously after being started. The automatic stapling machine is continuous in operation. It folds the cartons into position for fastening and the cartons are carried on a conveyor to the anvil where the wire staples are driven through the flaps of the box. This type of machine offers no appreciable hazard to the operator because the stapling operation is performed at such a distance from the person feeding the machine that he could not get caught in it.

The arm-type wire stitcher, however, offers considerable hazard to the operator who holds the carton while the wire is being driven. On large cartons some of the wire stitches or staples are more than an arm's length from the operator, but this is not true for all of them. In smaller cartons the operator's hands are within reaching distance of the point where stitching takes place. The hazard of this machine is that the finger of the operator may inadvertently be placed on the anvil and a staple driven through it. Such an injury can be painful, and it may result in permanent disability, particularly if infection should occur.

From the 1950 paperboard-container study, data for computing certain kinds of injury rates for stitching operations are adequate for all paperboard-container plants and for corrugated and fiber box plants. These rates are given in Table VI.

Table VI

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Average days lost or charged per case*	*Severity rate*
All manufacturing industries	14.7	0.8	84	1.2
Stitching operations:				
All paperboard-container plants	19.8	2.0	51	1.0
Corrugated and fiber box plants	21.5	1.4	[a]	0.9

[a] Average time loss not computed because of insufficient data.

Both the general frequency rate and, more important, the frequency rate of serious injuries, are considerably above comparable rates for all manufacturing industries combined. Although the average severity of such injuries is not high, the comparative frequency of serious injuries in stitching operations suggests that stitching or stapling machines are involved. The relative number of injuries caused by the arm-type machine or the automatic type is indeterminate, but by the very nature of the work, the arm-type machine with its hand feeding undoubtedly produces the greater proportion of injuries.

From the foregoing, the conclusion to classify the work of operating an arm-type, wire-stitching machine as particularly hazardous for minors seems warranted.

Sheeting Machine

The sheeting machine, or sheeter as it is sometimes called, is for the purpose of cutting a roll of paper into sheets as the paper passes through the machine. A rigid knife is mounted on a revolving arbor, the knife

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cutting through the paper at each revolution of the arbor.

The sheeting machine is automatic in operation after it has once been started. Paper is pulled from a free-running roll into the machine and after being cut into sheets is automatically piled on a table at the rear of the machine. No person actually operates the machine but the cut sheets must be removed from the rear. This is done without stopping the machine and it is possible to be injured by the cutting knife or by being struck by the arbor holding the knife. Sheeting machines are seldom guarded, and anyone working near or passing the machine could be struck by the arbor or knife it he should stumble. While less dangerous than some other paper products machines, it should not be operated by a young worker. Operating would include setting up and taking material away from the rear of the machine.

There are no statistical data specifically applicable to sheeting machines. Sheeting is a cutting operation, and, as previously noted, the cutting department is characterized by high frequency and severity rates.

Circular or Band Saw

Some fiber or corrugated paperboard is cut by power saws, either circular or band. Saws may be used to cut slits in partitions. When equipped with a dado head, circular saws are used to cut slots in some carton-making operations. Saws are hand-fed and often operated without guards.

Available injury data from the Bureau of Labor Statistics study of injuries in the paperboard-container industry throw no light on the degree of hazard of saws used for cutting paper or fiber board in the paper-products industries. Saws are used to such a limited extent that their accidents are not reflected in the injury rates.

Hazardous-Occupations Order No. 5 declares the operation of any power-driven woodworking machine particularly hazardous. Saws used to cut paper stock operate in the same manner as wood saws, their hazards are not less than wood saws, and there is every justification for classifying them as particularly hazardous.

Envelope Die-Cutting Press

Envelope blanks are cut out on a special type of press designed for that particular purpose. A heavy steel die—weighing up to 40 lb.—with a sharp cutting edge is placed on top of a ream of paper (about 4 in. in thickness) and a plunger forces the die through the paper. After each stroke of the press the die is picked up and placed at a new position on the paper and another 4-in. pile of blanks are cut out.

Some presses are single action, the press being actuated by a foot treadle for each stroke of the press. Others are continuously acting, the operator removing the die after the cut is completed and replacing it for the new cut as the press slowly reciprocates.

The operation of this type of die press is quite dangerous. Dies are heavy, as is a ream of paper (about 30 lb.), and the operator is constantly lifting or moving both die and paper. There is danger of dropping the die or cutting the hands while handling it. There is also the danger that the operator's hands will be caught between the descending ram and the die or paper. This is particularly true of the continuously acting press. The operator must work fast and accurately to locate the die on the paper so that a perfect cut is secured in the short period of time between strokes. Considering that operation involves constant handling of heavy dies and paper, that dies are sharp, and that there is a possibility of being caught in the press, work of operating an envelope die-cutting press is too dangerous for young workers.

The Bureau of Labor Statistics study of injuries in paperboard-container plants did not include envelope manufacturing and no statistical data are available on injuries due to envelope die-cutting presses.

Punch Press

Many machines employing the principle of the punch press are used in converting paper or paperboard into a semifinished or finished product. Within the industry they may not be referred to as punch presses but by a name more closely related to their function such as "window cutters" (presses for cutting windows in envelope blanks), "thumb hole" presses for cutting a thumb hole in manila envelopes, "embossing press" for impressing a design, "paper-lace machines" for making paper-lace doilies, "blanking presses" for cutting out paper cup blanks, "merchandise-marking" or "shipping tag" machines for blanking out these paper products. Punch presses are used for many die-cutting or embossing operations in practically all branches of the industry.

Punch presses may be either hand or automatically fed, the latter being used on long-run production jobs. In many cases the paper is fed into the press directly from a roll, the press operating continuously. The only thing the operator does is to put on a new roll of paper as needed, and to inspect the cut-out blanks to see that the quality is maintained. Automatic feeding is also used for secondary operations, that is performing a cutting or embossing operation on a previously cut blank. Where secondary punching operations are automatically fed, feeding may be done by a suction cup from the top of a pile of blanks, or feeding may be from the bottom of the pile by a mechanical device of some kind. Where automatic feeding is employed, the inherent hazard of the punch press is largely overcome because the operator does not need to reach into the die zone. The protection afforded the operator is more nearly complete if the press is guarded with a fixed barrier guard which will prevent the operator from placing his hand under or between the dies.

Hand feeding is much more dangerous. It is employed where a relatively small number of pieces are to be made, or where the product is of such size or shape that mechanical feeding is difficult. Since most paper stock is relatively thin and little power is required on the ram, limiting the ram stroke to less than one-quarter inch is often possible and this offers some protection to the operator. Other guards such as sweep guards, gate guards, or two-handed tripping devices are used much less frequently on punch presses in the paper-products industries than on punch presses in the metal industries. Since paper is easy to cut, much less power is required and consequently presses are smaller than presses used in the metal industries but their hazards are the same.

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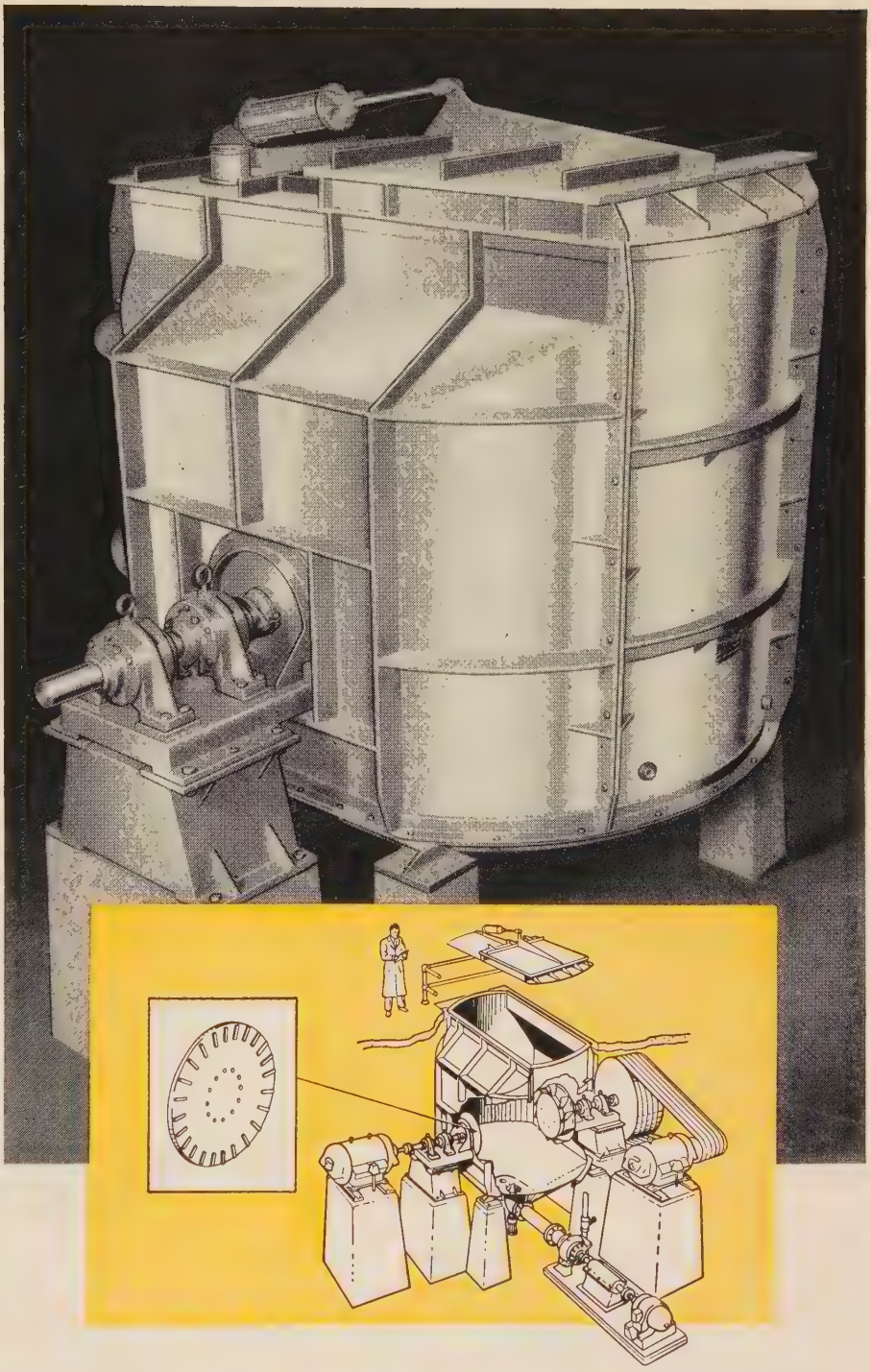

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No statistics on injuries caused by punch presses in the paper-products industry are available. Punch presses are usually used to perform a cutting operation and, as previously pointed out, injury frequency and severity rates from cutting operations are, in general, high. But no statistical data are available to indicate to what extent injuries caused by punch presses influence these rates.

The operation of punch presses, except those provided with full automatic feeding and ejection, used for cutting metal has been declared hazardous under Hazardous-Occupations Order No. 8. Since the hazards for punch presses in the paper industries are similar, the same treatment is warranted and all hand-fed punch presses should be classed as particularly hazardous.

Corner Cutter or Mitering Machine

In making setup boxes a special type of punch press is used for cutting away corners before the box blank can be folded. The machine operates continuously the operator holding the board to be cut under the die of the machine. The machine operates fairly slowly, but the length of stroke of the ram is sufficient for the operator's fingers to get under the die. The point-of-operation is unguarded and if the worker's finger is caught under the die, it may be amputated or severely injured.

The 1950 special survey of injuries occurring in the paperboard-container industry shows injury rates for corner-cutting operations. They are given in Table VII.

Table VII

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Severity rate*
All manufacturing industries	14.7	0.8	1.2
Corner-cutting operations:			
All paperboard-container plants	17.5	3.9	1.5
Setup box plants	22.7	5.7	2.1

These rates indicate a great degree of hazard in corner-cutting operations, especially in the high frequency of serious injuries and in the severity of injuries occurring in these operations in setup box plants. It is very probable that most of this hazard is due to corner-cutting machines.

Corner cutters should be considered in the same class as other punch presses, and the same limitations on employment of minors should apply.

Corrugating and Single or Double-Facing Machine

The corrugating and single or double-facing machine is a machine which combines by gluing continuous sheets of plain paperboard (liners) to one surface of a corrugated center (filler) to form single-faced corrugated paperboard, or when paperboard liners are placed on both sides of the corrugated center, to form double-faced corrugated paperboard. A cut-off unit at the discharge end cuts the corrugated paperboard into sheets.

The machine is a huge machine, entirely automatic in operation after it has been set up and started. It is operated by a crew, usually eight men on a large machine, consisting of one operator, two shafters, one inspector, and four off-bearers. But regardless of the fact that it is automatic in operation, crew members frequently get hurt. Injuries are caused by working about machines, rather than at the point-of-operation, as is the case in other machines previously discussed.

The operator is a skilled workman; he is in charge of the crew and must be able to assist in all phases of the work.

The two shafters who handle the paper rolls are subject to injury from material handling. Rolls of paper, weighing up to 1000 lb. or more are placed in position at the rear of the machine, usually by an overhead crane. The shafter places a steel spindle through the hollow core of the roll of paper and mounts it on the roll stand. A mechanical hoist is used, the hoist may be independent of the roll stand or it may be an integral part of the roll stand. There is danger of crushed fingers or toes from handling the heavy rolls of paper, also danger from strains. Shaftless roll stands as used on some modern machines eliminate some of the hazards found in the shaft-type machines. In threading the paper between the rolls, fingers or hands may be caught in the pinch-point. Rolls are heated and contact with the rolls can cause a burn; the glue also is heated, offering possibility of burns.

The off-bearers work at the discharge end of the machine. As the corrugated paper leaves the machine in a continuous strip, other operations such as slitting or scoring take place. The last operation is cutting-off to size. The off-bearers take the cut-off pieces and pile them for transportation to the next operation. The work is heavy and is done at a fast pace. Strains and sprains are a source of injury, also falls, the floor about the take-off end becoming cluttered with scrap.

The inspector works about the machine to see that the product is up to quality. He is exposed to moving machinery, hot glue, and heated rolls. Some observations must be made from raised platforms or runways alongside the machine which offer possibility of falls.

Injury rates for corrugating operations in the paperboard-container industry are given in the 1950 special survey made by the Bureau of Labor Statics. These rates are given in Table VIII.

Table VIII

Operation	*Frequency rate, all disabling injuries*	*Frequency rate, serious injuries*	*Average days lost or charged per case*	*Severity rate*
All manufacturing industries	14.7	0.8	84	1.2
Corrugating operations:				
All paperboard-container plants	42.5	1.7	91	3.9
Corrugated and fiber box plants	47.7	1.9	92	4.4

These injury rates show a high degree of accident hazard in corrugating operations, from the stand point of both frequency and severity of injury. The general frequency rate and the severity rate for corrugating operations in corrugated and fiber box plants were higher than for any other production operation in the paperboard-container industry. The average time lost or charged per disabling injury was exceeded by only one production operation—printing in folded-box

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Both instruments are successfully operating in the paper industry—users' names on request. Both are sold on a money back guarantee of satisfaction.

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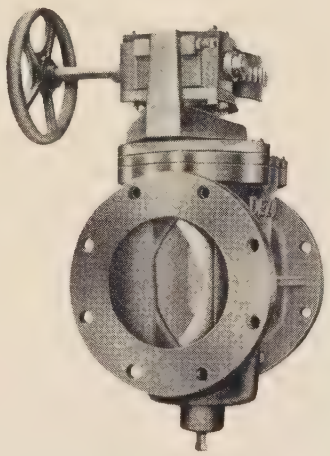
It's the ideal valve for throttling service on pulp and paper stock lines. The rate of discharge remains constant at any setting—there is no build-up of stock in the orifice . . . . no "eddy point" where stock can pack. This stable operation results in extremely accurate control.

DeZurik Vee-Port Valves provide decided advantages on refiner systems, pump discharge lines, and other points where production and quality depend upon delivery of a steadfast, uniform volume of stock.



DeZurik Vee-Port Valves are available in sizes 3" thru 16", in a broad range of materials. Lever and gear operators can be furnished to provide dead-tight shut-off where required. Positioning type cylinder operators are available for automatic level control, stock feed to fan pump, basis weight or caliper control and similar services.

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SARTELL, MINNESOTA

plants, which had an average time charged of 111 days. The frequency rate of serious injuries for corrugating operations, while not so high as for some other operations, was nevertheless twice as high as the corresponding rate for all manufacturing industries combined.

While it is true that most of the hazards of working about the corrugator and single or double-facer are not at the point of operation, nevertheless, the closely related hazards—falls, strains, crushed fingers and toes, etc.—are sufficient to warrant classifying all work in connection with the machine as particularly hazardous.

Laminating or Combining Machine

A laminating or combining machine is for the purpose of combining two or more sheets of paper or paperboard to form a multiple-ply product by applying an adhesive and running the paper through various pressure rolls. It is also known as a fiber paster.

This machine is to fiber box stock what the corrugating and combining machine is to corrugated stock. The only difference is that none of the paper goes through a corrugating roll, all of the paper combined into the fiber stock being flat. Fiber stock may also be heavier, three, four, or more plies of paper being glued together under pressure to form a single sheet of tough heavy fiber. The process being the same, the hazards are the same, and the same conclusions with respect to the employment of minors would apply.

No statistics are available on injuries caused by this type of machine.

CONCLUSIONS

Some machines in the paper-products industries are inherently dangerous to operate and guarding methods presently in use, while diminishing to some extent, do not entirely eliminate the hazards. On the basis of inherent hazard, substantiated by what statistical data are available on injuries, the following occupations are particularly hazardous for minors under 18 years of age.

Operating or assisting in the operation of the following power-driven paper-products machines: scrap paper baler, guillotine paper cutter or shear, hand feeding of platen die-cutting presses, hand feeding of platen-printing presses, horizontal bar scorer, vertical slotter, arm-type wire stitcher or stapler, sheeting machine, circular or band saw, envelope die-cutting press, hand-fed punch press, corner cutter or mitering machine, corrugating and single- or double-facing machine, and laminating or combining machine.

41st Annual Meeting

of the

Technical Association

of the

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Hotel Commodore, New York, N. Y.

February 20–23, 1956

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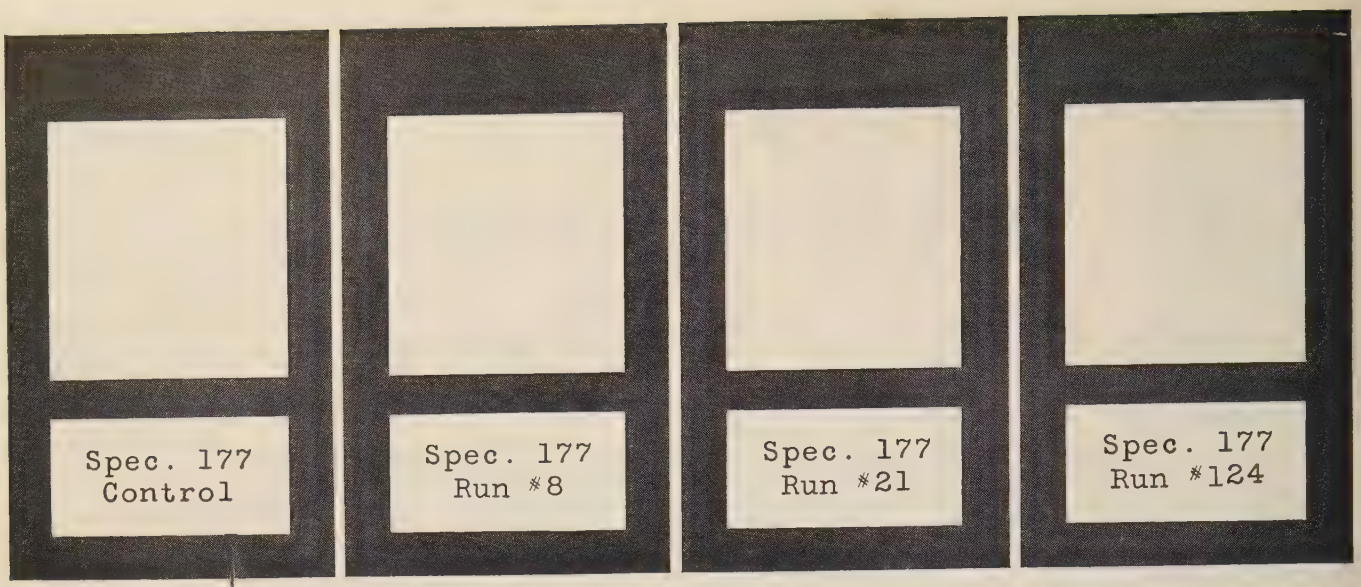

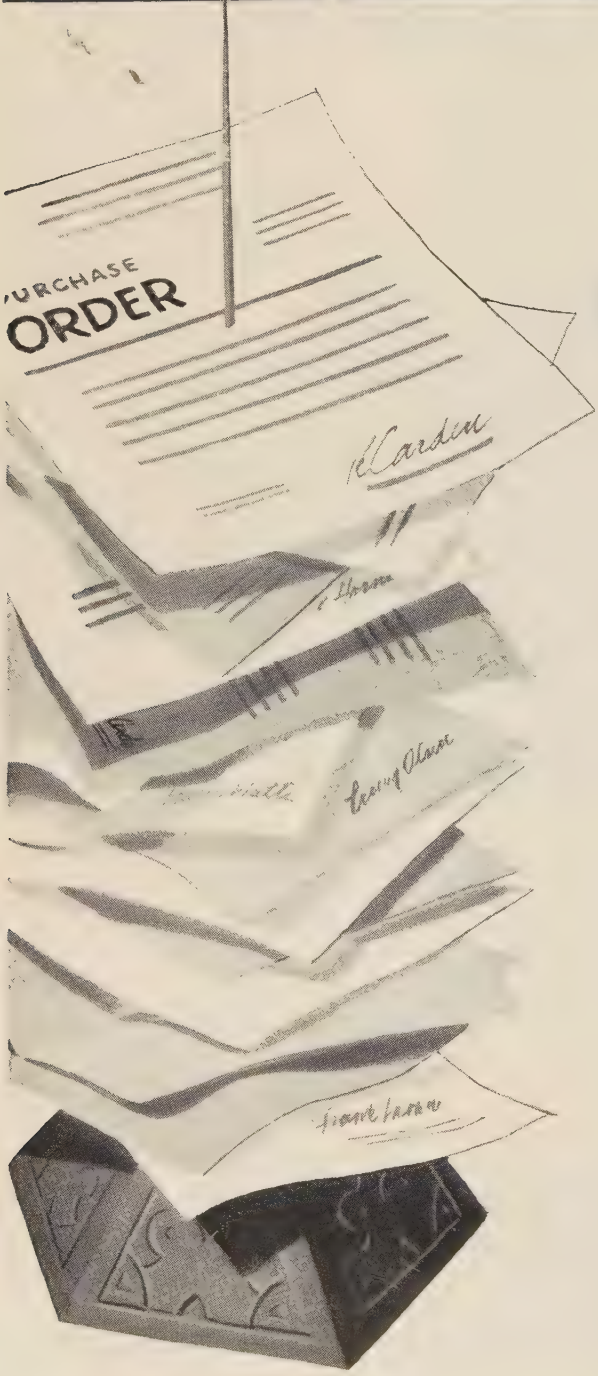

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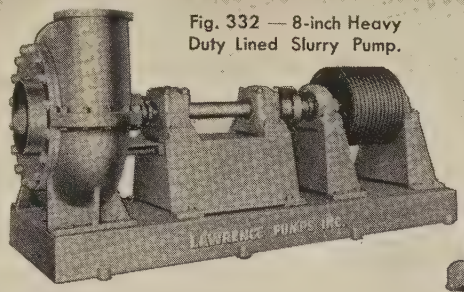

Fig. 332 — 8-inch Heavy Duty Lined Slurry Pump.

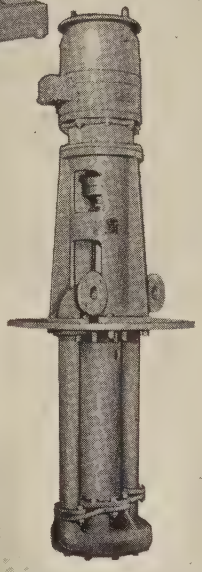

Fig. 244 — 4-inch Vertical Submerged Pump With No Bearings Below the Cover Plate.

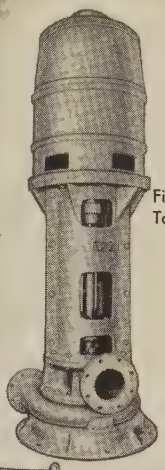

Fig. 285 — 5-inch Vertical Top Suction Stock Pump.

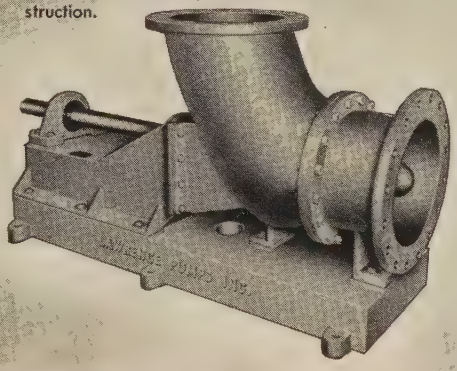

Fig. 333 — 24-inch Horizontal Circulating Propeller Pump of Nickel Alloy Construction.

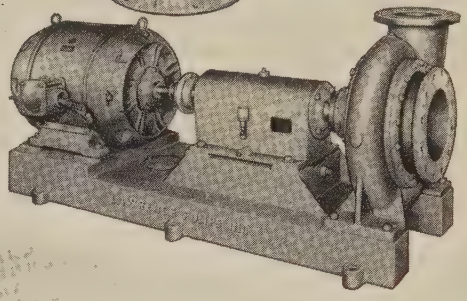

Fig. 337 — Lawrence 10-inch Heavy Duty Stainless Steel Chemical Pump.

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for the pulp and paper industries

LAWRENCE PUMPS *handle every liquid and fluid material used in pulp and paper mills*

To pump acids, caustics, stocks, resins, sulphurs, slurries — hot (1500°F), cold (—347°F), or extremely viscous — requires engineering skill normally not available from a pump manufacturer. Lawrence engineers have specialized in this difficult field for more than 90 years. It may almost be said — there is no "pumpable" fluid with which Lawrence engineers have not had repeated and successful experience.

Lawrence Pumps are designed for either horizontal or vertical operation. Every pump is custom built from the corrosion- and abrasion-resistant metals best-suited to the fluid to be pumped.

If you have a particularly difficult pumping problem, we can save you both time and money. Write us the pertinent details. No obligation.

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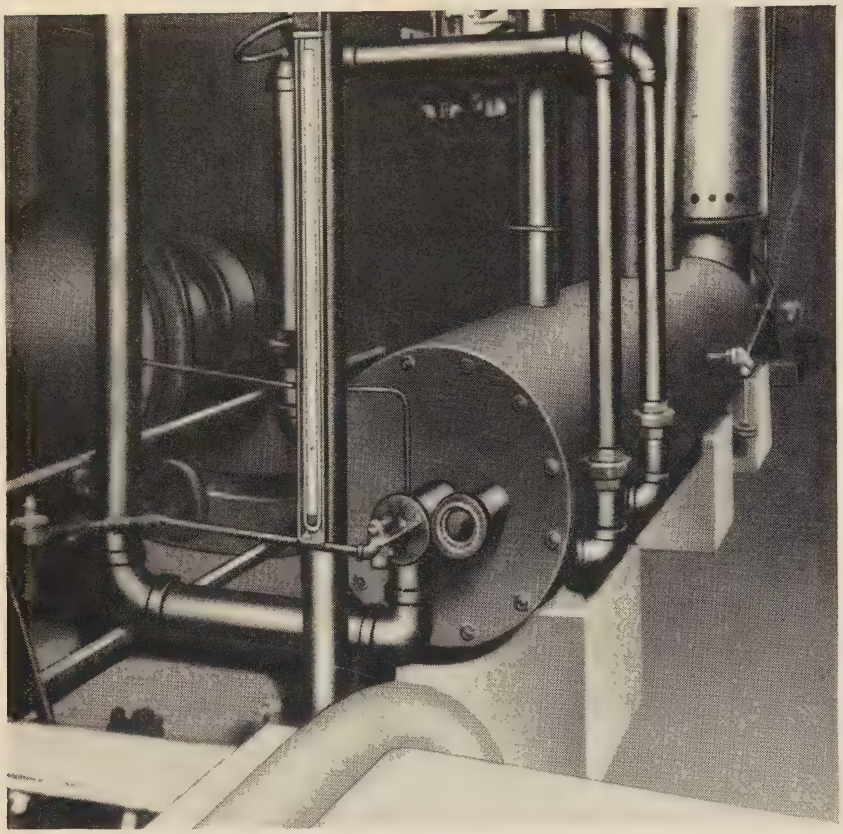
LAWRENCE PUMPS INC.

357 Market Street, Lawrence, Massachusetts

An Important New Development in Sulphur Burning . . .



Commercial installation of Chemipulp-KC 2½-ton sulphur burner. Note the compact design as compared with conventional burner shown in the background.

Chemipulp-KC *Jet Type* Sulphur Burner

More Compact—
More Efficient

Handles Any Type of Sulphur

Long Life—
Low Maintenance Costs

Fast Start-Up
Instant Shut-Down

In the new Chemipulp-KC Burner the molten sulphur is sprayed into the burner as a fine mist. The secondary heated air is then introduced in several stages, resulting in clean operation and long service life.

Because of the small mass, the burner quickly reaches its maximum efficiency temperature of 2100° F., minimizing the production of SO_3. This burner operates efficiently at all SO_2 gas concentrations between 12% and 18½%. At its operating temperature of 2100° F. the bitumen in the dark sulphur is completely burned, so that dark sulphur as well as bright sulphur is efficiently burned. Shut-down is instantaneous.

This unusually compact unit is now available in capacities of 1, 2½, 5, 12, 15 and 25 tons per day, and each different size burner operates efficiently at loads of 25% to 150% of rated capacity. Both installation and maintenance costs of this new burner, which is a development of the KIMBERLY-CLARK CORPORATION Research Program, are considerably lower than rotary burners and combustion chambers of equal capacity.

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Associated with Chemipulp Process Ltd., 403 Crescent Bldg., Montreal

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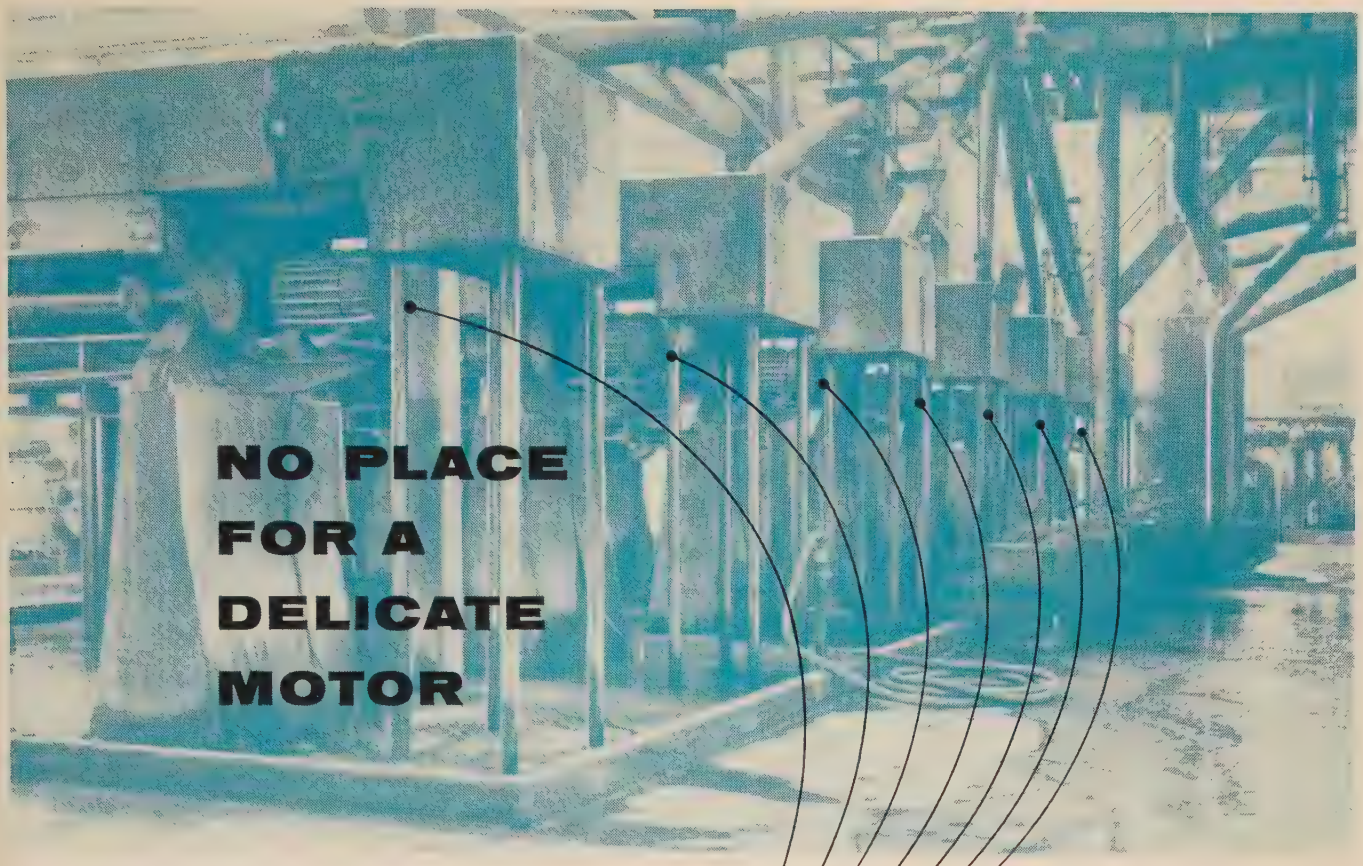
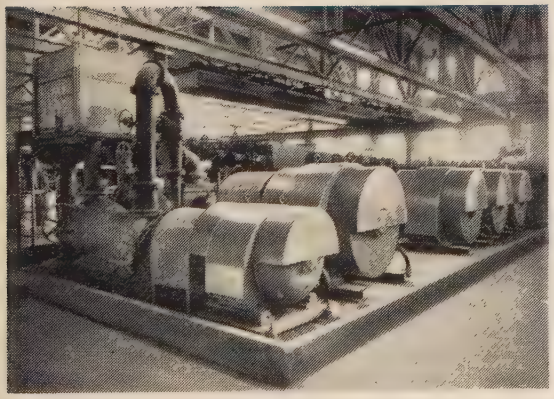


ELLIOTT C-W MOTORS ARE BUILT TO TAKE IT ON TOUGH MILL DRIVES

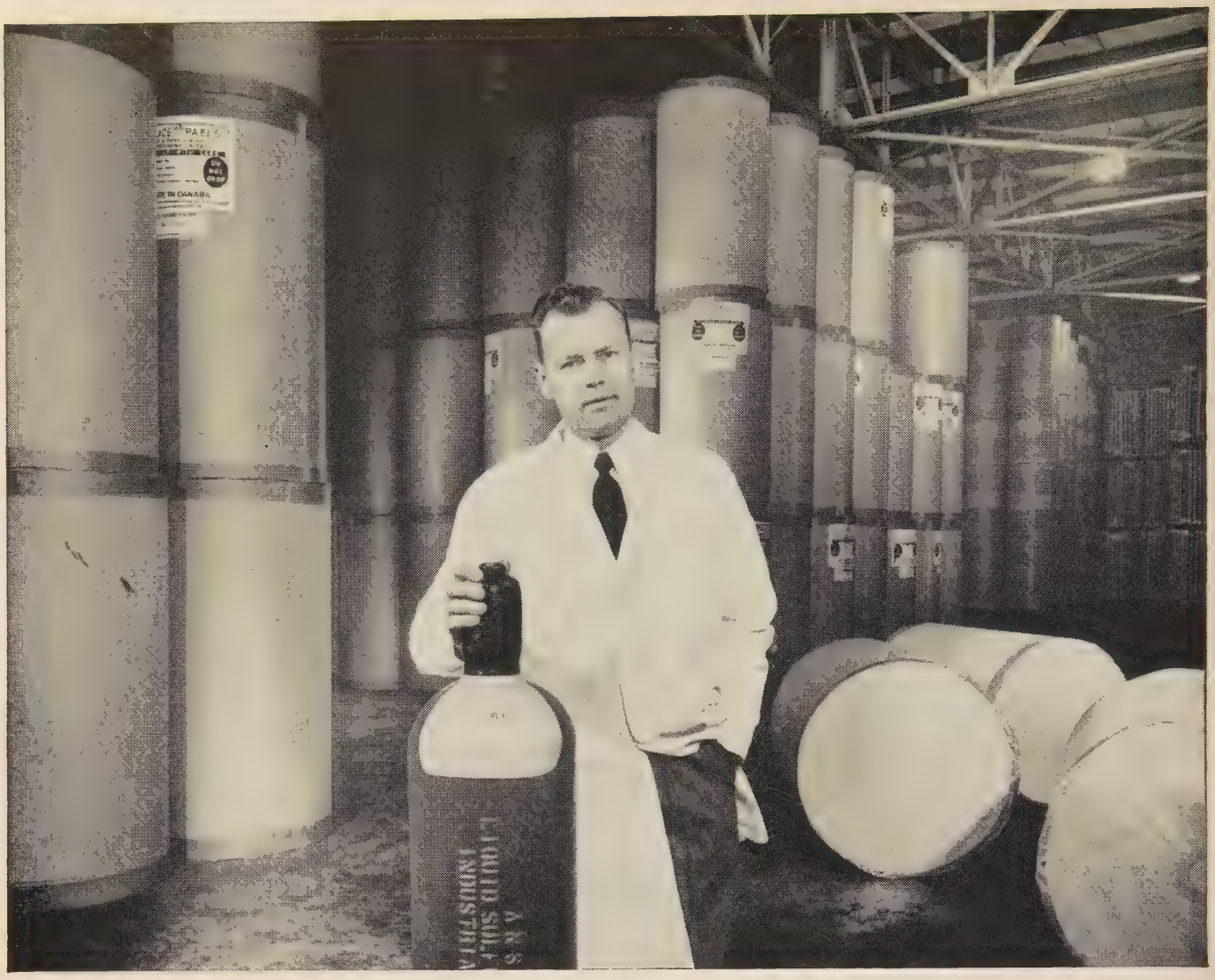


Five Elliott C-W splashproof motors driving various pulp refiners in a New England mill. The 250-hp, 1170-rpm motor in the foreground, drives a hydrafiner. Beyond are two 200-hp, 435-rpm motors driving jordans and two 200-hp motors driving unifiners.

WHEN STOCK PASSES THROUGH this row of 14 plate, flat-bed screens, it often foams up and spills over the top, dripping and splashing on the motors below. The result? No damage or costly production holdups because these are rugged Elliott C-W TEFC Sealedpower motors on the job. They are effectively sealed against the invasion of liquids and other foreign matter. At the same time, they are *cool*-running and *long*-running, seldom requiring maintenance at all.

Other types of Elliott C-W motors perform equally well on other drives. Splashproof motors, for example, prevent splashing liquids from entering ventilating openings. Wound rotor motors, in open, dripproof, splashproof or TEFC models, are popular for a-c drives requiring slow, smooth acceleration and other special requirements. Check with your local Elliott Field Engineer or write Elliott Company, Crocker-Wheeler Division, Jeannette, Pa. for complete details.

ELLIOTT Company



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"Use of the liquid SO_2 and reliable counsel and service by Ansul personnel, definitely got us over the hump. We were able to maintain the high quality of our refining process during a difficult period. An impressive factor was the ease with which we were able to control the liquid SO_2 absorption system. All in all, the operation was very successful."

There are many advantages gained by installing an Ansul SO_2 system on a permanent or on a stand-by basis. The Ansul SO_2 system can be started and stopped immediately; rates of flow and degrees of concentration can be changed instantly.

Ansul sulfur dioxide is also used in chlorine bleaching, in peroxide bleaching and in semi-chemical pulping. Write us for more information. ANSUL CHEMICAL COMPANY, Dept. C-47, Marinette, Wisconsin.

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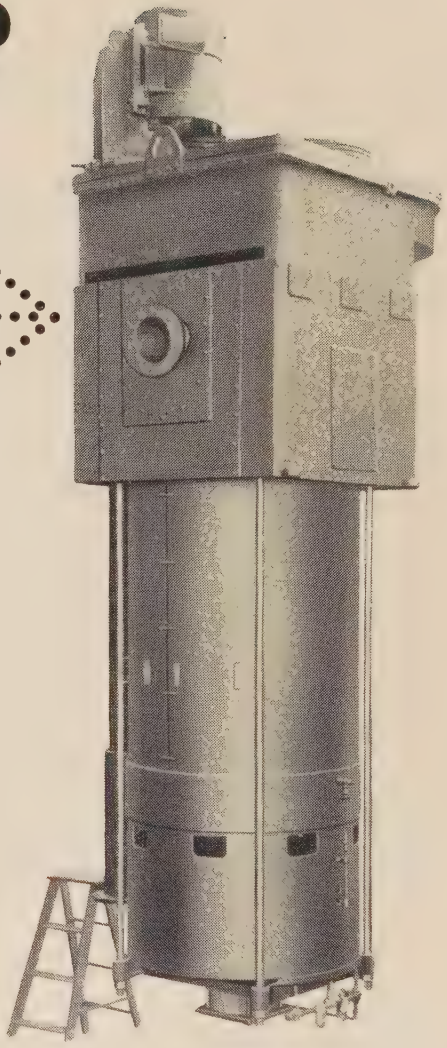

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NEW JACKSON & CHURCH SYSTEM OF "CRUMB TRANSPORT" CUTS LABOR AND MAINTENANCE COSTS... SAVES TIME AND MONEY!

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A minimum of labor is involved in either pressing or handling. Capital expense is lower than with any other method. J-C Pulp Press installations are available in capacities of 25 ton to 300 ton units.

Write today for additional information about this new Jackson & Church system of "crumb" transport . . . now in successful commercial operation in custom and integrated mills.

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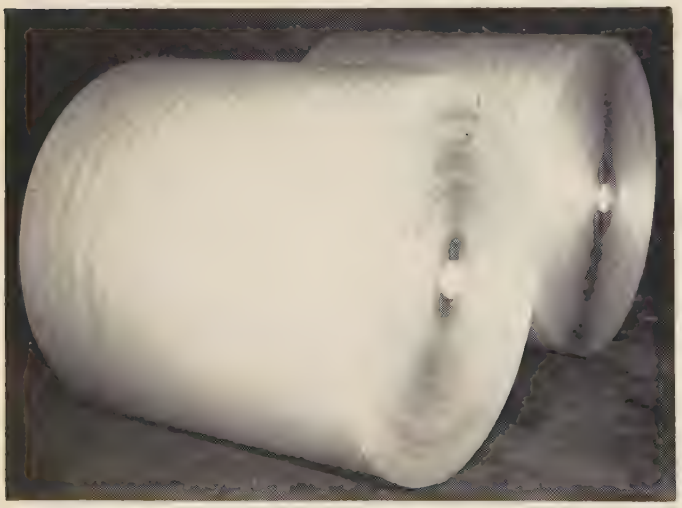
Work well done since eighty-one

HUYCK FELTS HELP

CROSSETT PAPER MILLS PRODUCES 850,000 LBS. OF KRAFT EVERY 24 HOURS in its modern mill at Crossett, Ark. Company plans for 1955 include a neutral sulfite semi-chemical pulp plant and a new 216″ cylinder machine.



ROLLS OF CROSSETT Converter Items [*at left*] made from perpetual forest reserves, include multiwall sack, asphalting, creping, envelope, gumming, grocery bag and specialties. **CROSSETT'S MERCHANT ITEMS** [*at right*] are wrapping and butcher papers in rolls and sheets.

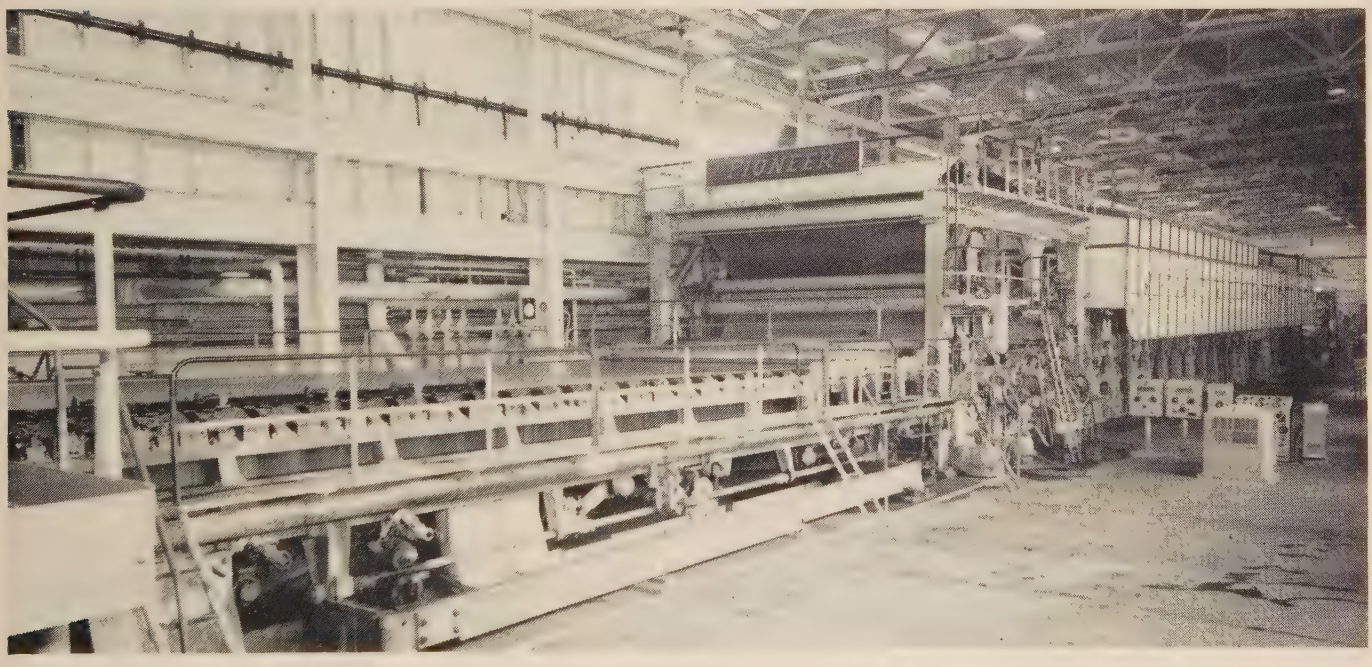
TO SET A NEW RECORD

Operating on All 3 Positions of a Beloit Fourdrinier Machine at CROSSETT PAPER MILLS...

Late last year . . . skilled papermakers of Crossett Paper Mills, a Division of the Crossett Company, Crossett, Ark., scored a new record—*running 30-lb. Kraft at 2,024 feet-per-minute for 8⅓ hours, without a break!*

The record run was made on Crossett's advanced-engineered "Pioneer" machine, with all 3 of its positions clothed by Huyck felts.

Papermakers attribute the *above par* performance of Huyck machine clothing to our continuing development of *new techniques* in felt-making . . . the fact that there are more *plus advantages* in felts trademarked Huyck.



THE "PIONEER" MACHINE which set the new production speed record. Operated by Crossett's championship team of papermakers, the machine used 1 suction transfer pick-up felt and 2 press felts made by Huyck.

HUYCK FELTS

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Established 1870

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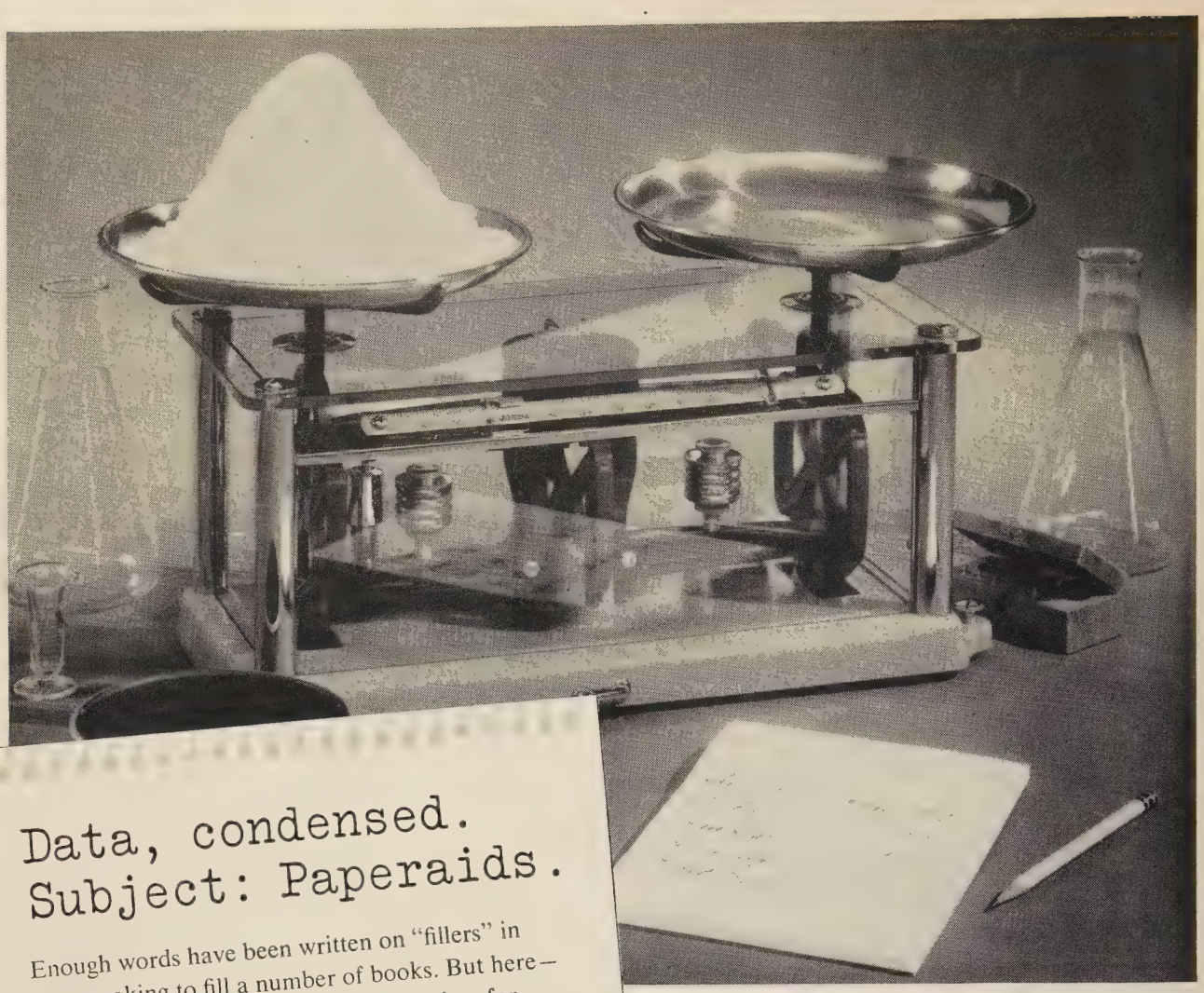


Data, condensed. Subject: Paperaids.

Enough words have been written on "fillers" in papermaking to fill a number of books. But here—compressed into 57 second's worth of time for quick and easy review—are the important physical properties which give Dicalite paperaids their many values.

RANGES DEPENDING ON GRADE

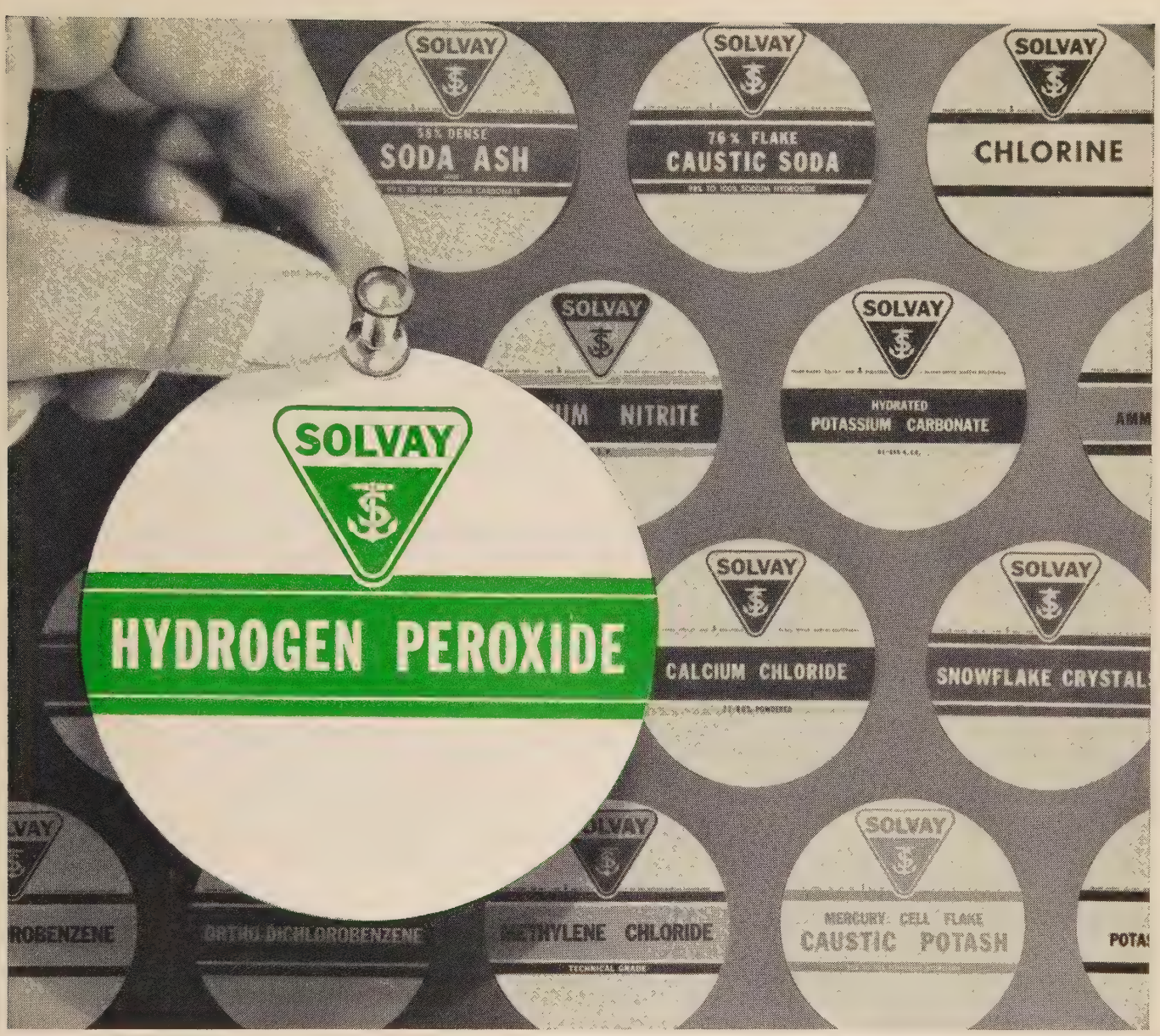
COLOR: Cream white, buff white and pure white.
BRIGHTNESS: 56 to 90.
MOISTURE, Maximum: 0.5% to 6%.
PARTICLE SIZE: Fineness varies from 3% to 10% retained on 325 mesh screen.
POROSITY: 70% to 95%.
SURFACE AREA: 10,000 to 150,000 sq. ft./lb.
DENSITY: 9 to 11 lb./cu. ft. loose weight. Specific gravity, 2.00 to 2.35.
ABSORPTIVENESS: 120 to 300% of weight of Dicalite.
WETTABILITY: Excellent.
INERTNESS: Essentially inert in acid and aqueous solutions.

Add to these properties the unique interlacing structure formed by Dicalite's tiny particles, and you have the basic reasons why, in papermill after papermill, Dicalite is providing such advantages as: (1) increased retention of fine fibers and pigments (2) better fiber distribution for more uniform sheet formation (3) improved color and greater opacity (4) better printability (5) faster drainage on the wire and quicker drying on the rolls (6) excellent control of pitch, wax and asphalt. And these do not complete the list of Dicalite's values in papermaking.

Write us for more complete information.

Dependable GLC GREAT LAKES **Dicalite®** DIATOMACEOUS MATERIALS

DICALITE DIVISION, GREAT LAKES CARBON CORPORATION, 612 SOUTH FLOWER ST., LOS ANGELES 17, CALIFORNIA



A NEW Solvay Product

Solvay Hydrogen Peroxide, the latest addition to Solvay's line of alkalies and industrial chemicals, is being produced in a new plant at Syracuse, New York. This new plant, which represents the latest advances in chemical engineering, is designed to assure hydrogen peroxide users a product of highest quality—Solvay quality.

Solvay Hydrogen Peroxide will be produced in both 35% and 50% grades, and will be shipped in both drums and tank cars. It will be available in straight or mixed carloads or truckloads, as well as in less carload quantities. We invite your inquiries about prices and general information.

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Soda Ash • Hydrogen Peroxide • Snowflake® Crystals • Chloroform
Ammonium Bicarbonate • Cleaning Compounds • Caustic Potash
Sodium Nitrite • Ammonium Chloride • Chlorine • Caustic Soda
Methylene Chloride • Monochlorobenzene • Para-dichlorobenzene
Ortho-dichlorobenzene • Methyl Chloride • Carbon Tetrachloride

SOLVAY PROCESS DIVISION
ALLIED CHEMICAL & DYE CORPORATION
Allied Chemical
61 Broadway, New York 6, N. Y.

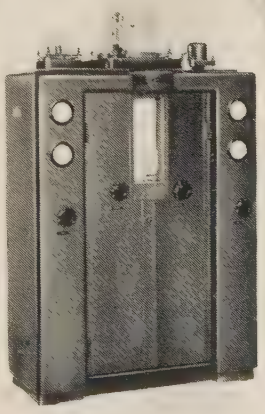
BRANCH SALES OFFICES:
Boston • Charlotte • Chicago • Cincinnati • Cleveland • Detroit • Houston
New Orleans • New York • Philadelphia • Pittsburgh • St. Louis • Syracuse

PAPER

KEEPS COMING...
...AND COMES

CLEAN

WITH W&T CHLORINATION



No slime formers . . . no contaminating organisms . . . no objectionable tastes, odors or colors . . . paper keeps coming without a slime break, and comes *clean* when a Wallace & Tiernan Chlorination system safeguards the fresh and white waters.

Whether your mill produces pulp, newsprint, kraft, writing, tissue, or board, the quality of your product and the efficiency of your mill depend on clean, biologically pure water. For information on how to get biologically pure water most economically, write our Industrial Division.

WALLACE & TIERNAN
INCORPORATED
25 MAIN STREET, BELLEVILLE 9, N.J.

1-50

For wet strength right off the reel

PAREZ® Resin 607...

A MELOSTRENGTH® Resin

When *Sales* calls for rush orders of wet-strength paper, *Production* can meet the deadlines with PAREZ 607. For PAREZ Resin 607 delivers up to 75-80% of its ultimate wet strength right off the reel—no aging or curing, no waiting to check shipments.

And PAREZ 607 also...

- gives consistent results from grade to grade in all common pulps
- works well over all normal pH ranges
- improves wax and rosin size efficiency
- is a MELOSTRENGTH resin, backed by the national MELOSTRENGTH Promotion Program

Get the full story on PAREZ 607 from your Cyanamid representative today.

CYANAMID OFFERS PAPER CHEMICALS *for every industry need—each backed by technical experts with years of practical mill experience.*

Mill Applications of Cyanamid's Paper Chemicals...

Size costs cut 16%. That's what a northern board mill reported recently when they switched from regular rosin size to CYFOR® Fortified Rosin Size. The mill found that with the switch, size consumption was reduced one third. Savings in freight are plus advantages not included in the 16% savings.

* * *

Dye costs drop one third. When a western mill started using small amounts of ACCOCEL® 741 Dispersant as a mordant in bleached stock, it was found that only two thirds of the basic dye was required. More even color throughout the sheet was another important gain.

* * *

Rewinding production boosted 50%. In running butchers' wrap, a southern mill was troubled with "skidding" or slipping of the paper when rewinding into small rolls. Then ALWAX* 251-S Wax Size was tried. When the size was added properly at the beater at the rate of 6 pounds of size solids per ton of paper, the machine ran trouble-free and rewinding speed was upped 50%.

* * *

The symbol below identifies paper made with PAREZ Resin 607 as possessing superior properties. It is backed by the national MELOSTRENGTH Promotion Program, designed to increase the use of paper everywhere.

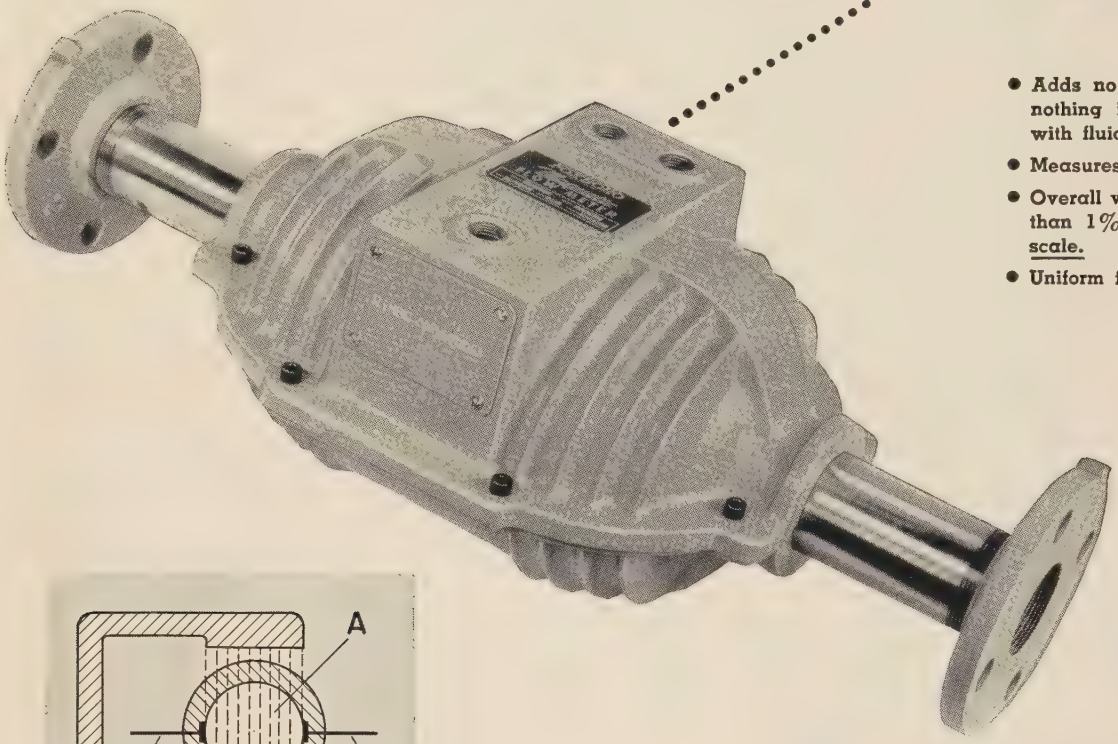
*Trade-mark

melostrength* paper
Wet or Dry . . It's Stronger

AMERICAN Cyanamid COMPANY
PAPER CHEMICALS DEPARTMENT
30 Rockefeller Plaza, New York 20, N. Y.

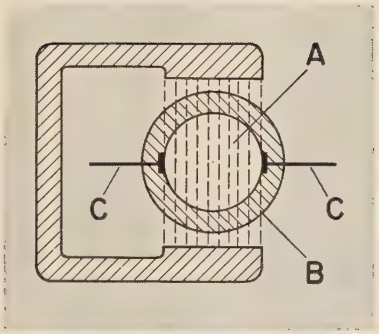
In Canada:
North American Cyanamid Limited, Toronto and Montreal

NEW! a flow meter with no flow restrictions!



- Adds no pressure drop — nothing inside pipe to interfere with fluid flow.
- Measures fluid velocity directly.
- Overall volumetric accuracy better than 1% of range over entire scale.
- Uniform flow scale.

FOXBORO MAGNETIC FLOW METER



SIMPLE, TROUBLEFREE, OPERATION

The Foxboro Magnetic Flow Meter operates on the same principle as a power generator. A magnetic field (A) is maintained through a standard pipe section (B) of stainless steel or other non-magnetic material. This pipe section is lined with Kel-F® or other insulating material. Liquid passing through pipe acts as moving conductor, generating an electric voltage which varies in proportion to liquid's average velocity. Flush electrodes (C) in pipe wall "pick up" this voltage which is recorded in desired flow units by Dynalog Electronic Recorder or Controller.

For pulp stock of any consistency, thick black liquor, corrosive chemicals, or any other paper mill liquid — this entirely new-type meter accurately measures flow *magnetically*. It completely ignores such common metering headaches as turbulence, suspended solids, and variations in conductivity, density and viscosity. It even measures reversing flows!

Installation is simple. The magnetic spool piece connects into the line like any equivalent length of pipe — no seals, purges, meter runs or straightening vanes required. Connects by 2-conductor cable to remote Dynalog Electronic Flow Recorder. Integrator and controller components can be added.

Maintenance is practically eliminated. There are no pressure taps to become plugged or frozen, no working parts to foul.

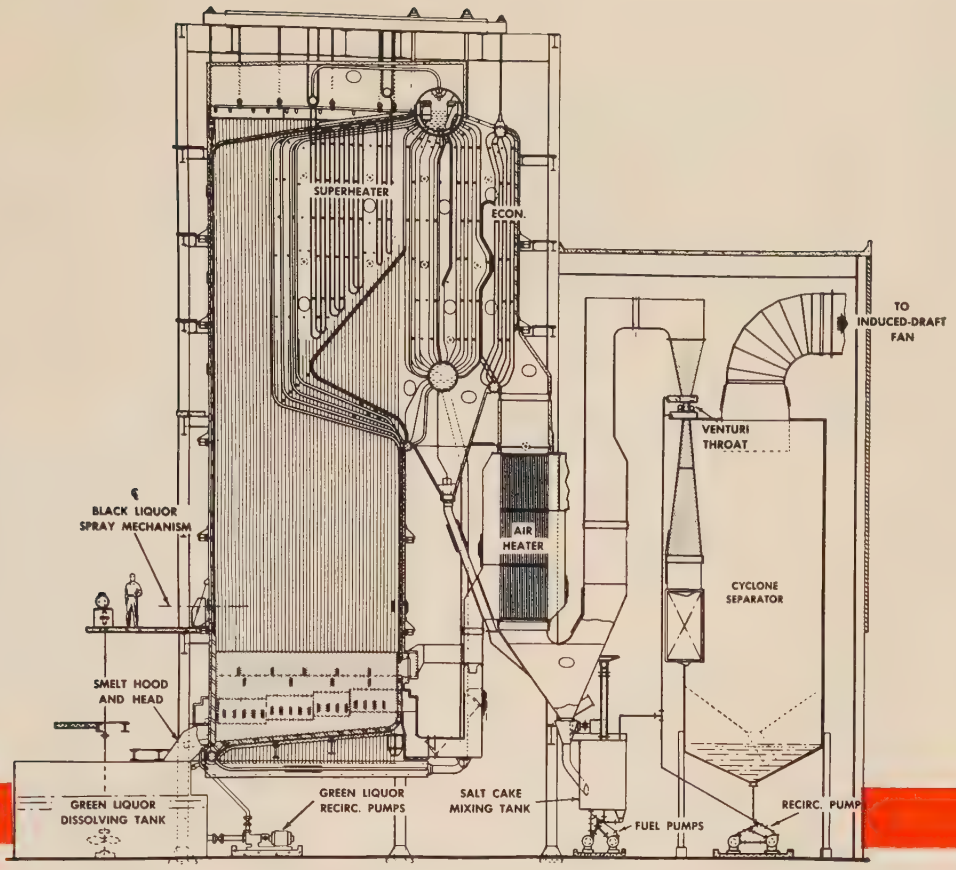
Learn how this precise, troublefree meter can help *your* processing. Write for complete details of the Foxboro Magnetic Flow Meter.

THE FOXBORO COMPANY, 7810 NEPONSET AVENUE, FOXBORO, MASS., U. S. A.

FOXBORO
REG. U. S. PAT. OFF.

Foremost in FLOW METERING

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND



Venturi Evaporator-Scrubber

(Contact Liquor Evaporator) (Fume Collector)

Installed with B&W Recovery Unit at THILCO P&P COMPANY PRODUCTS means Improved Economy

The Babcock & Wilcox Company black-liquor recovery system illustrated above has completed two years of continuous trouble-free operation at THILMANY.

An outstanding feature of this installation is the B&W Venturi Evaporator-Scrubber, which combines in one piece of equipment both the concentration of black-liquor and collection of salt cake fume. The two-year operating period has proved the Venturi Evaporator-Scrubber to be completely reliable and highly efficient.

Two recovery units equipped with Venturi Evaporator-Scrubber are now in service. Four additional units ranging in capacity from 117 to 300 pulp tons are currently on order.

The Venturi Evaporator-Scrubber is an important addition to B&W's equipment for black-liquor recovery. B&W can select exactly the right combination for your mill, as in the case of Thilmany Pulp and Paper Company.

Advantages of the B&W Venturi Evaporator-Scrubber unit include:

- Easy and Simple to Operate
- Low First Cost
- Increases overall Thermal Efficiency
- Efficient use of operating force
- Reduces Maintenance Requirements
- Continuous, High, Fume Collection Efficiency
- Minimum space requirement
- Reduces multiple effect evaporator load.

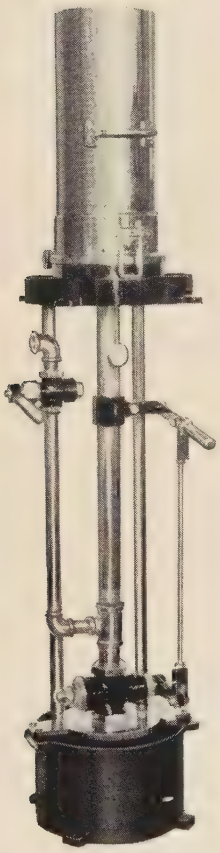
BABCOCK & WILCOX

BOILER DIVISION

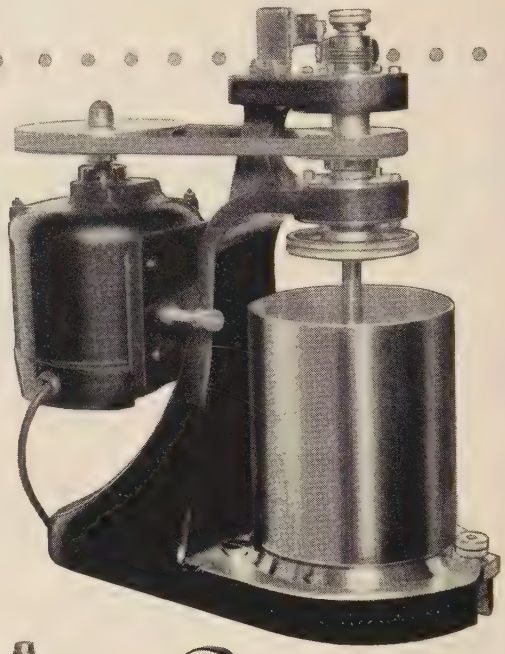
P-787

TAPPI STANDARD

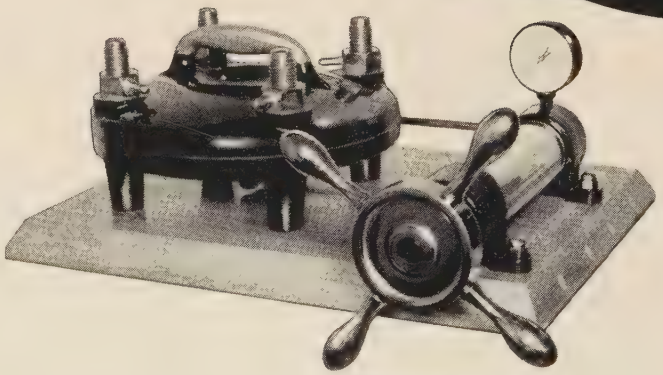
Pulp Testing and Sheet Making Apparatus



TAPPI
Sheet Making
Machine



TAPPI
Disintegrator



TAPPI
Pump and
Press

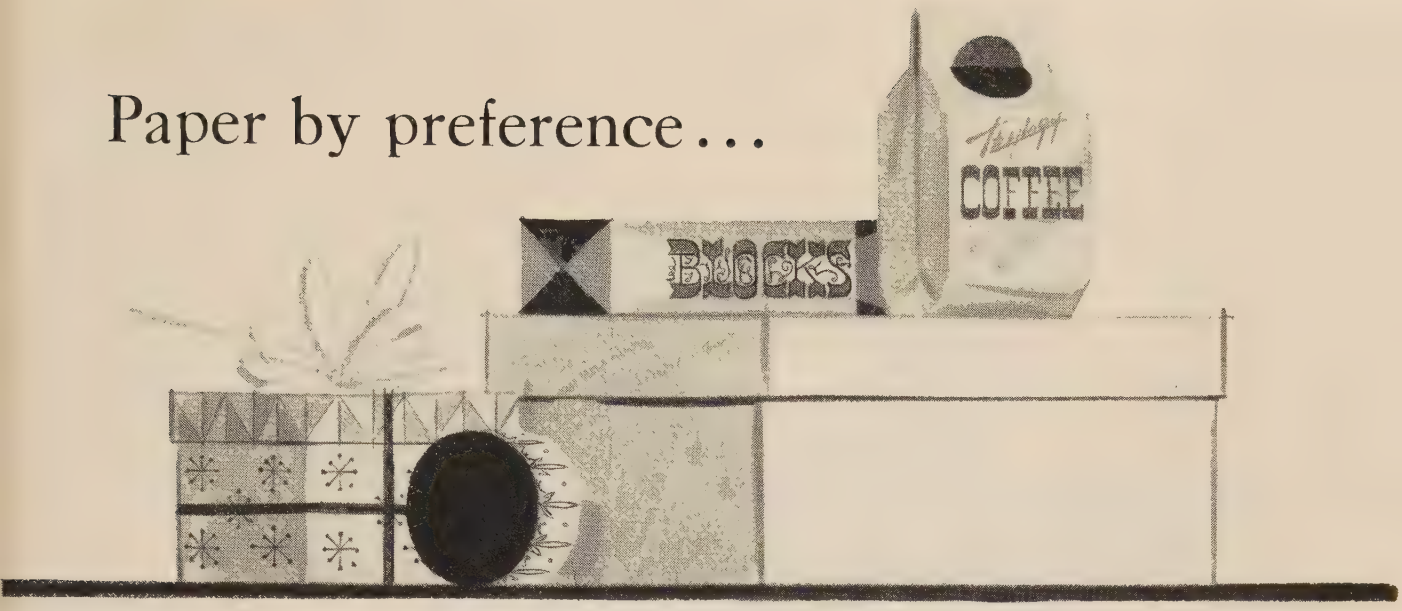
Write for complete information Today!

Also Available...
AUTOMATIC COUCHING AND PRESSING EQUIPMENT
as developed by Hermann Mfg. Co.

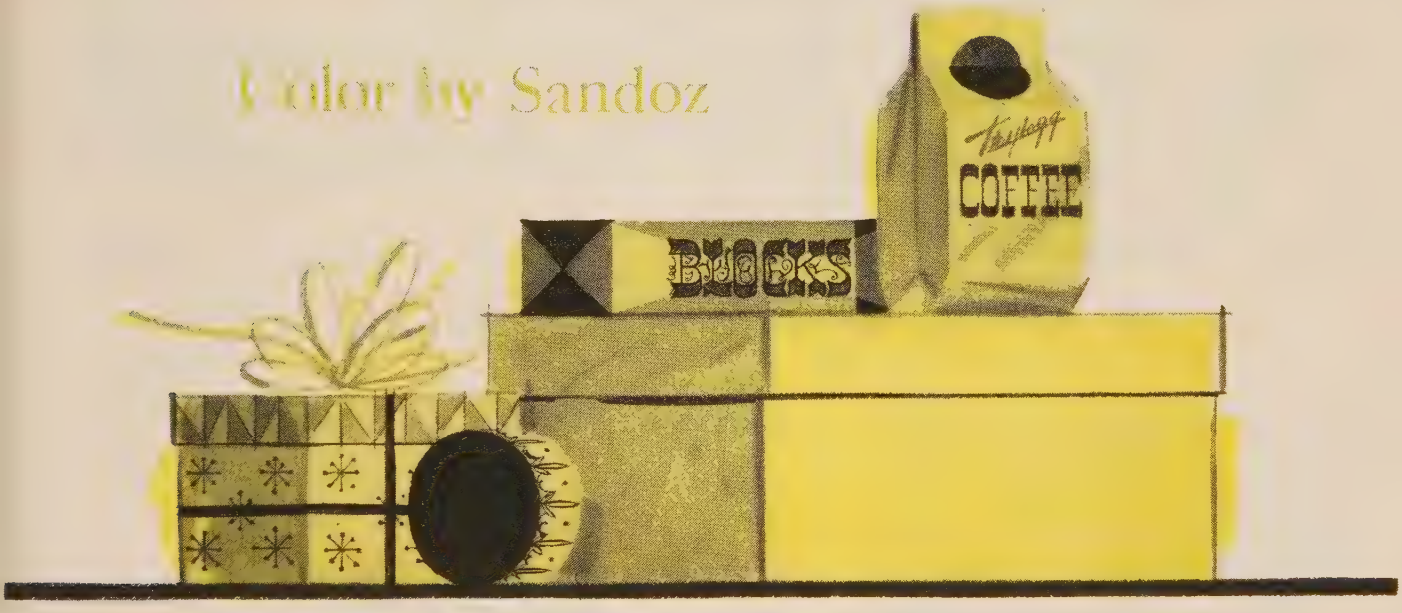
Automatic
Press

THE HERMANN MANUFACTURING CO.
LANCASTER, OHIO

Paper by preference...



Color by Sandoz



New products, new uses, new customers every week of the year! Paper with color-appeal is building tremendous new markets—new profit opportunities.

For sales-making color in your products, Sandoz produces a complete line of dyestuffs (such as the Sandoz Trisulfon Yellows) and chemicals. You can count on the Sandoz staff for fast and effective service on any new problem that may arise.

Your nearest Sandoz branch is as close as your telephone:

CHARLOTTE 1, N. C.
1510 Camden Road
Edison 2-1197

CINCINNATI 26, OHIO
3712 Beechmont Ave.
East 1335

FAIR LAWN, N. J.
Fair Lawn Ave. & Third St.
Fair Lawn 6-2800

HUDSON, MASS.
312 Main Street
Hudson 1260

LOS ANGELES 13, CALIF.
467 East Third Street
Mutual 1-1158

PHILADELPHIA 34, PA.
2215 E. Tioga Street
Delaware 6-4040

*MONTREAL (Que.) CANADA
P. O. Box 364, Station "B"
Marquette 4-517

*TORONTO (Ont.) CANADA
179 King St. West
Empire 8-2975

SANDOZ CHEMICAL WORKS, INC.
61-63 Van Dam St., New York 13, N. Y.

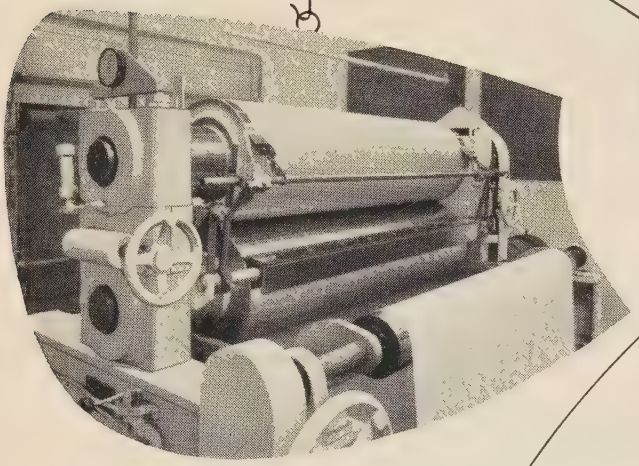
*In Canada: Sandoz (Canada) Ltd.

SANDOZ

SANDOZ
THINKS AHEAD WITH PAPER

Still another installation by a leading producer demonstrates the advanced planning and efficiency of Frank W. Egan & Company design. This TREATER was chosen to produce Formica laminated sheets for decorative and industrial applications because it turns out the highest percentage of perfect material and treats the base stock *uniformly*. An Egan exclusive is the micrometer gauge for exact control and finest adjustment *while operating*.

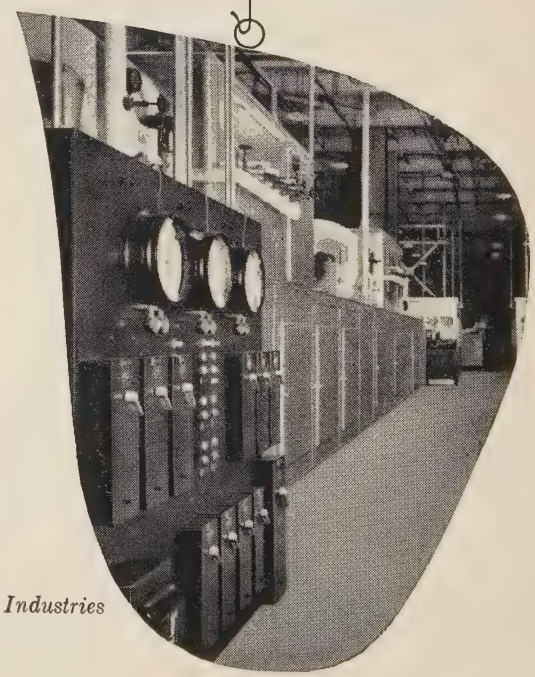
Egan



Treater

FOR LAMINATED PLASTICS INDUSTRY

Supplied to THE FORMICA COMPANY



Egan
FRANK W. EGAN & CO.
SOMERVILLE, N.J.

FRANK W. EGAN & COMPANY, Somerville, New Jersey

Designers and Builders of Machinery for the Paper Converting and Plastics Industries

Cable Address: EGANCO—SOMERVILLE (NJER)

Representatives: WEST COAST — John V. Roslund, 244 Pacific Bldg., Portland, Ore.
MEXICO, D. F. — M. H. Gottfried, Avenida 16 De Septiembre, No. 10.

Licensees: GREAT BRITAIN — Bone Bros. Ltd., Wembley, Middlesex. FRANCE—Achard-Picard, Remy & Cie, 36 Rue d'Enghien Xe, Paris. ITALY— Emanuel & Ing. Leo Campagnano, Via Borror ei 1 B/7, Milano. GERMANY— ER-WE-PA, Erkrath, bei Dusseldorf,

"Fire destroyed wax...normal supplier said 3 weeks... Cities Service delivered truckload same day"

Out of wax at 8. A.M., dairy receives truckload from Cities Service by noon the same day.

Fire had destroyed the entire supply of wax at Country Charm Dairy, Monticello, Illinois—and to replace it through the normal supplier would have taken three to four weeks, meaning an equivalent shut-down.

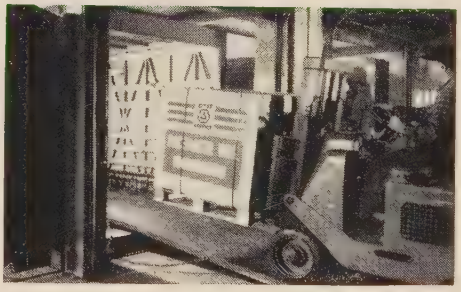
But President R. C. Miller said he'd have no delay . . . and at 8 A.M. he conceived the idea that saved him from it. He called the Cities Service Representative who'd been supplying his lubricating oils and inquired about wax. By noon that same day, the dairy was back in operation with a truckload of Pacemaker Wax direct from the Cities Service warehouse!

"Ever since, we've been using Pacemaker Wax and the service has kept at a par with our first emergency order," says Mr. Miller. "Cities Service Technical Personnel have helped us every step of the way and thanks to their aid and the excellent sealing and penetrating properties of Pacemaker Wax, our cartons are greatly improved. Needless to say, we're happy to recommend Pacemaker Wax to any wax user."

You'll profit by following Mr. Miller's recommendation. Contact your nearest Cities Service office or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, N. Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

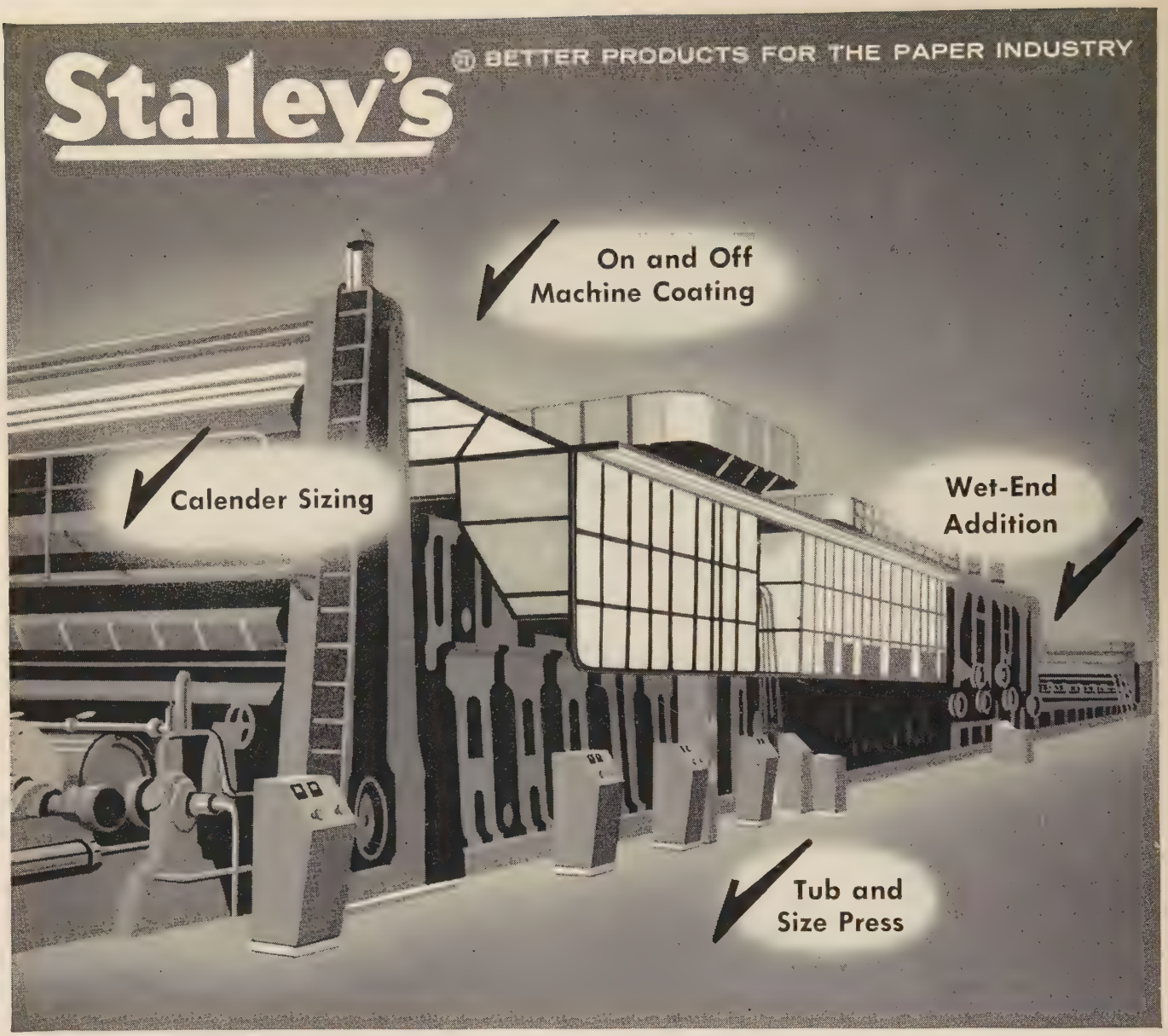


Local Warehousing of Cities Service Pacemaker Wax saved the day for Country Charm Dairy. Completely out of wax at 8. A.M. one morning, due to fire, President R. C. Miller called Cities Service and received entire truckload by noon the same day.

Cartons coated with Pacemaker Wax are greatly improved, according to Mr. Miller. He also praises the aid received from Cities Service Technical Personnel. "I'd recommend Cities Service to any wax user," he says.

Staley's

BETTER PRODUCTS FOR THE PAPER INDUSTRY



From Furnish to Finish . . .

A Stayco Starch for every papermaking need

Staley's Stayco Starches are custom manufactured, oxidized starches for wet end, tub and size press, on and off machine coating, and calender applications. Highly effective in any of these operations, this versatile, easily handled starch can answer your physical production control problems. Uniform quality and performance standards assured in a complete range of 5 viscosities—Stayco S, A, G, C and M. Stayco can be cooked to a highly dispersed colloidal solution; at the same time it makes an exceptionally strong binder or size, and has superior film forming characteristics.

See your Staley Paper Representative soon . . . get the complete story on how Stayco Starches can ease your production control problems and help you to make higher quality paper products. Or write to us for details.

A. E. Staley Manufacturing Company, Decatur, Illinois

Branch Offices: Atlanta • Boston • Chicago • Cleveland • Kansas City • New York • Philadelphia • San Francisco • St. Louis

From Furnish **Stayco** *To Finish*

PRODUCTS FROM CORN Staley's AND SOYBEANS

QUALITY PAPER PRODUCTS

Coating Starches and Dextrins
Beater Starches
Calender Starches
Specialty Gums

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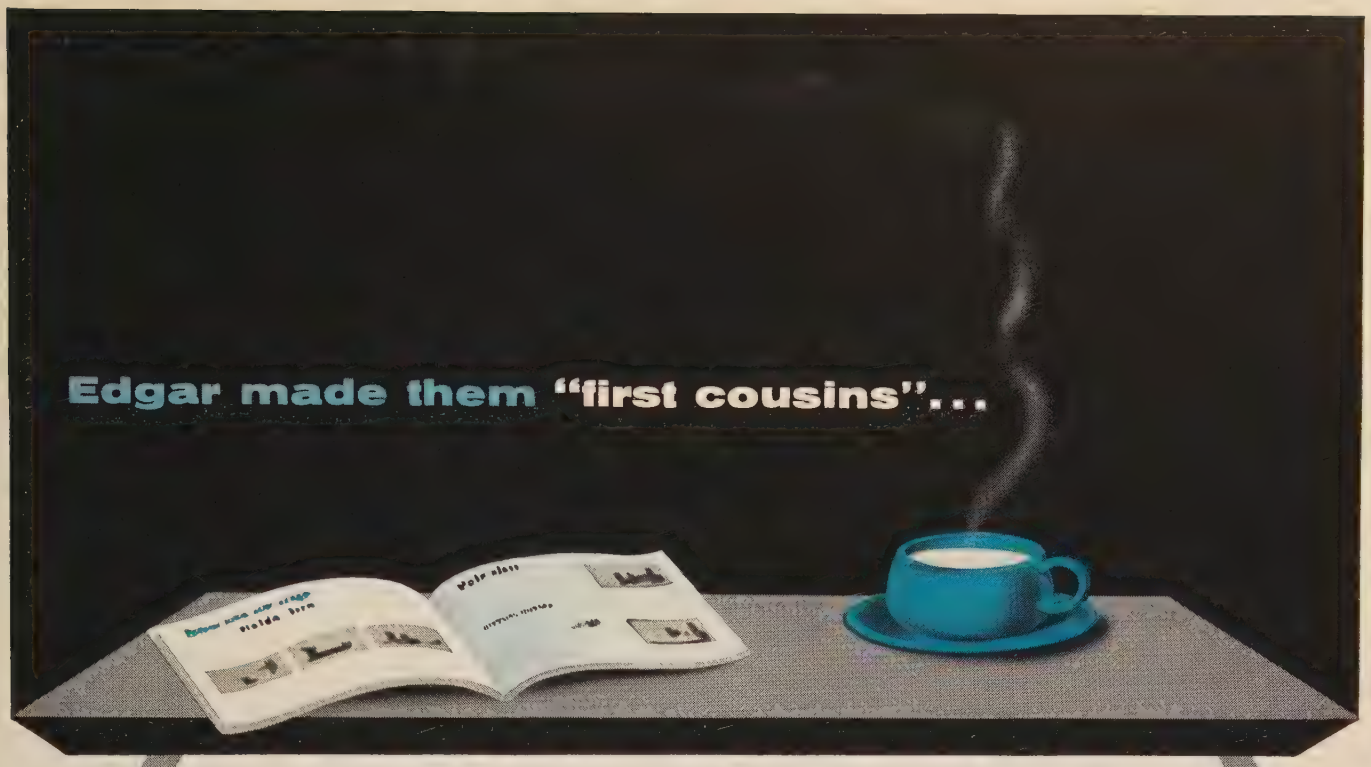

to give you highest sheet standards

Edgar Clay technicians were *first* to "Spray Dry" paper coating clays—the same process used to make your morning's instant coffee.

Results? Ultra-uniform coating clays that do amazing things to paper quality.

Today's "slick" magazines—and countless other printed messengers—owe their bright, smooth finish to this processing milestone. The means and the end are inseparable "first cousins."

Papermakers reap wide benefits from EDGAR Coating Clays, and the modern processing and quality control methods behind them. High brightness, low moisture, minimum residue, controlled viscosity, plus *true uniformity* . . . all are unvaryingly yours in *every* car, year in, year out.

Edgar Spray Dried Products

SPRAY-SATIN Coating Clay: A fine fraction, spray dried, predispersed coating clay with unmatched uniformity, low moisture content, excellent make-down properties, high bulk density, and high brightness. Specially fractionated—ideal for both high and low solids machine and conversion coating and size press coating applications.

PREDISPERSED HT Coating Clay: A spray dried, predispersed, intermediate fraction machine and conversion coating clay suitable for both high and low solids applications . . . excellent for size press pigmentation.

Here's Help For You: To help you select the EDGAR *Paper Clay most suited to your particular requirements, there have just been published the full specifications and basic properties of all* EDGAR *Coating and Filler Clays . . . a copy is yours without obligation . . . please use the coupon below.*

EDGAR PRODUCTS *from . . .*

MINERALS & CHEMICALS CORPORATION OF AMERICA
2 STATION PLACE, METUCHEN, N. J.

ALWAYS A BETTER WAY...

MINERALS & CHEMICALS CORPORATION OF AMERICA
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Please send me, without obligation:

- ☐ Basic Properties of Edgar Paper Clays.
- ☐ Other first-hand information and samples pertaining to:

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company_____

address_____

city_____ zone_____ state_____

Specified for THIRD

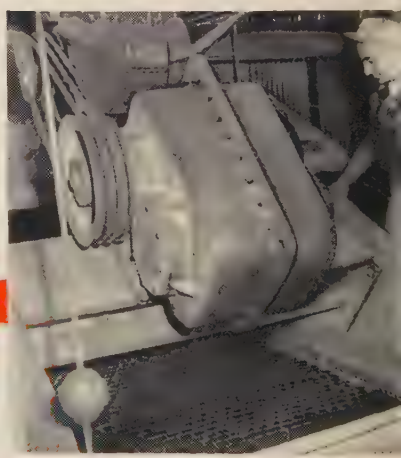
ALLIS-CHALMERS
Paper Mill EQUIPMENT

LIME SLUDGE KILNS

Burning precipitated calcium-carbonate sludge to lime in causticizing plant. Allis-Chalmers kilns offer fuel savings of as much as 40% with increased capacity, can reduce lime costs as much as 50%.

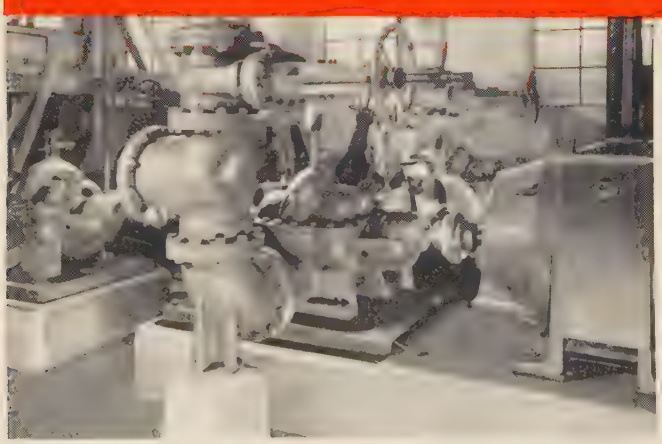
CONTROL

Factory-assembled Type HALS 2300-volt, 0.8 pf, three-phase, 60-cycle synchronous motor starter units installed on balcony above controlled motors. Motors are Allis-Chalmers synchronous types, six 400 rpm, 400 hp driving Jordan refiners; and two 450 rpm, 450 hp driving Sutherland refiners.



CHIP SCREENS

One of 8 Allis-Chalmers double-deck *Low-Head* chip screens in operation at Potlatch Forests. These units operate continuously, screening 16 units of chips per screen every hour.



PUMPS

The fresh water used at Potlatch is supplied by eight of these 12 by 10, Type SG pumps. Four are driven at 1765 rpm by 250-hp Allis-Chalmers motors, four at 1775 by 160-hp motors.

ALLIS-

EXPANSION Program

Potlatch Forests, Inc., Again Chooses Allis-Chalmers Equipment . . . for Dependable, Efficient Operation

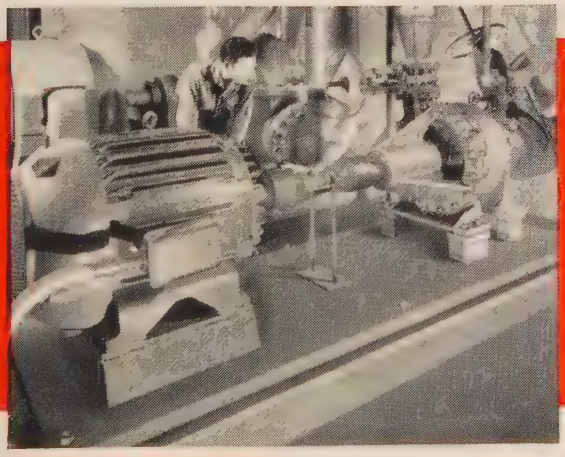
ALLIS-CHALMERS equipment, installed in their original plant, gave POTLATCH FORESTS, INC., of Lewiston, Idaho, the kind of service they needed.

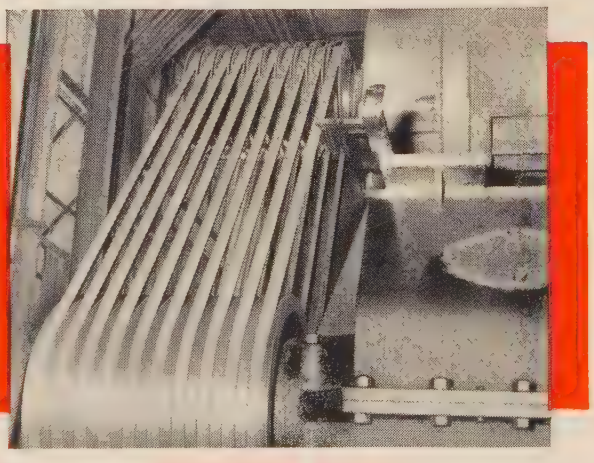
When the time came for expansion of their facilities, Potlatch Forests called on Allis-Chalmers again.

Allis-Chalmers engineers worked in close conjunction with the Potlatch planning staff to lay out the best possible plan for the required expansion.

Now finishing the third expansion program, Potlatch Forests reports that Allis-Chalmers equipment, operating in the expertly engineered flow, is paying off in maximum efficiency of machines and personnel.

For help with your paper mill equipment problems call your nearby Allis-Chalmers office or write Allis-Chalmers, Milwaukee 1, Wisconsin.





STOCK PUMPS

10 by 6, 750-gpm, 100-ft head, Type PWG pump moving unscreened bleach stock to flat screens. Driven at 1170 rpm by 60-hp induction motor.

TEXROPE DRIVE

10-groove, D section *Texrope* drive with stationary control *Vari-Pitch* sheave running pulp press—powered by Allis-Chalmers 125-hp, 900-rpm motor.

Texrope, Low-Head and Vari-Pitch are Allis-Chalmers trademarks.

CHALMERS

A-4819

Ti-Pure® gives bread wrap a "clean white" that sells

Fresh, "clean white" for bread and other food wrap helps complete the sale —both to your customers and the ultimate consumer. And to give bread wrap, waxed board, glassine and parchment lasting, sales-winning "whiteness," there's nothing like Du Pont TI-PURE titanium dioxide pigments.

Applied to bread wrap, TI-PURE improves its printability to make your customers' trade marks distinctive, easy-to-read . . . gives extra brightness and greater opacity. The same attractive combination of premium brightness and high opacity results when TI-PURE is added to other food wrap and container stock.

Time-tested TI-PURE pigments are now offered direct to you by Du Pont, and are sold only under the name, TI-PURE. For more information, or for help with a pigmenting problem, call our nearest district office. Our technical experts, backed by a modern paper laboratory, will be glad to help. There's no obligation, of course. E. I. du Pont de Nemours & Co. (Inc.), Pigments Department, Wilmington 98, Delaware.

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
. . . *THROUGH CHEMISTRY*

PROMPT, NATION-WIDE SERVICE THROUGH THESE DU PONT DISTRICT OFFICES* AND WAREHOUSES:

Atlanta, Ga.	*Houston, Texas	*Malden, Mass.	*Philadelphia, Pa.
*Chicago, Ill.	Indianapolis, Ind.	Minneapolis, Minn.	*Portland, Ore.
*Cleveland, Ohio	Kansas City, Mo.	New Orleans, La.	St. Louis, Mo.
Dallas, Texas	Lockland, Ohio	*New York, N. Y.	*San Francisco, Calif.
*Detroit, Mich.	Louisville, Ky.	*Pasadena, Calif.	Seattle, Wash.

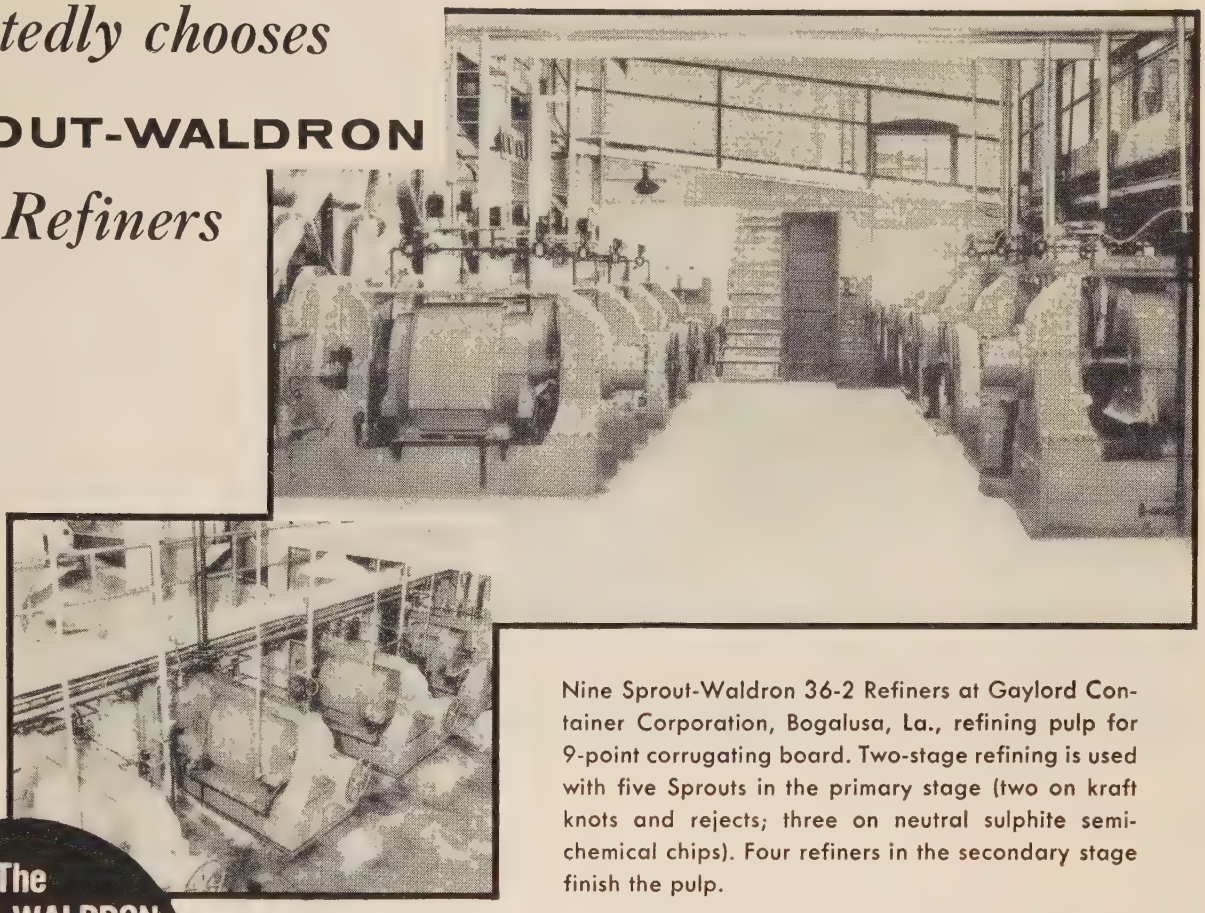
for economical **SEMI-CHEMICAL** *pulping*

GAYLORD CONTAINER CORPORATION

repeatedly chooses

SPROUT-WALDRON

36-2 Refiners



Nine Sprout-Waldron 36-2 Refiners at Gaylord Container Corporation, Bogalusa, La., refining pulp for 9-point corrugating board. Two-stage refining is used with five Sprouts in the primary stage (two on kraft knots and rejects; three on neutral sulphite semi-chemical chips). Four refiners in the secondary stage finish the pulp.

Sprout-Waldron Refiners have been producing pulp in this mill since 1931. Repeat orders are the best evidence of customer satisfaction.

The SPROUT-WALDRON refiner is the leading producer of semi-chemical pulp

Single rotating disc design with peripheral control ring plus rugged construction for . . .

- **High Pulp Quality**
- **High Capacity**
- **Flexibility of Operation**
- **Low Maintenance**

For more information on semi-chemical pulping or any other pulping application, send for our file of technical and practical data. Write to Sprout, Waldron & Co., Inc., 38 Logan St., Muncy, Pa.

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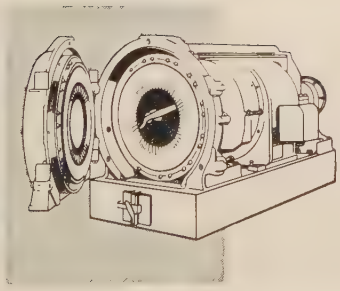

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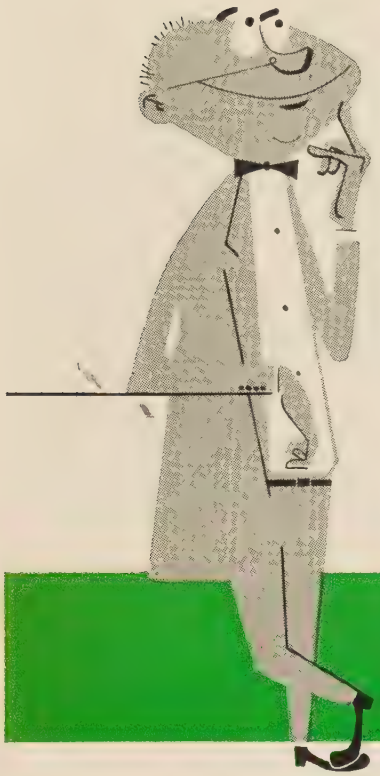

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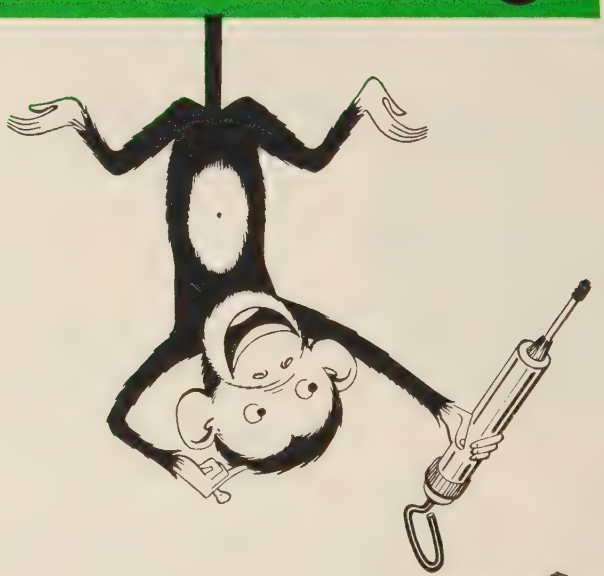

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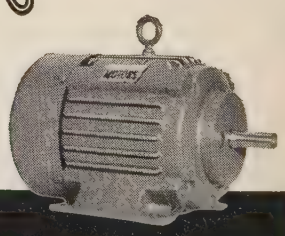

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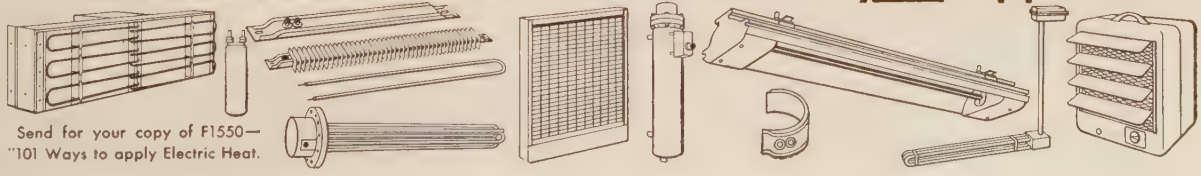

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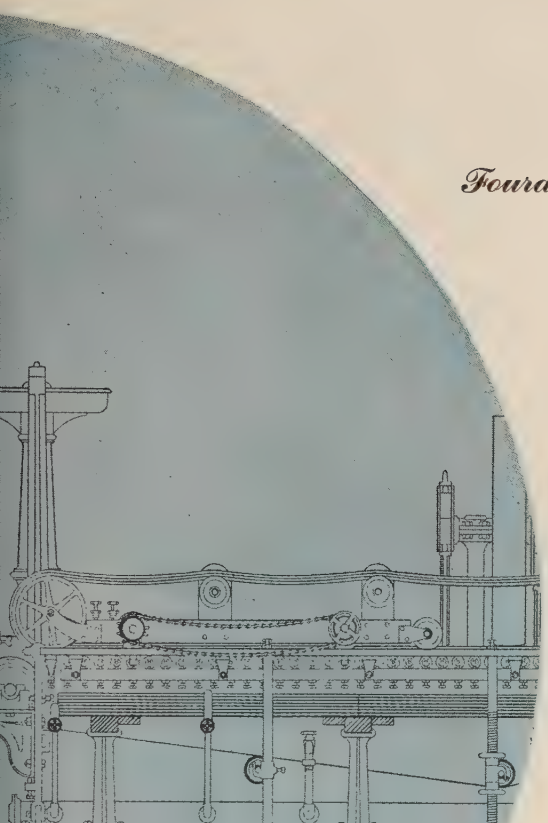

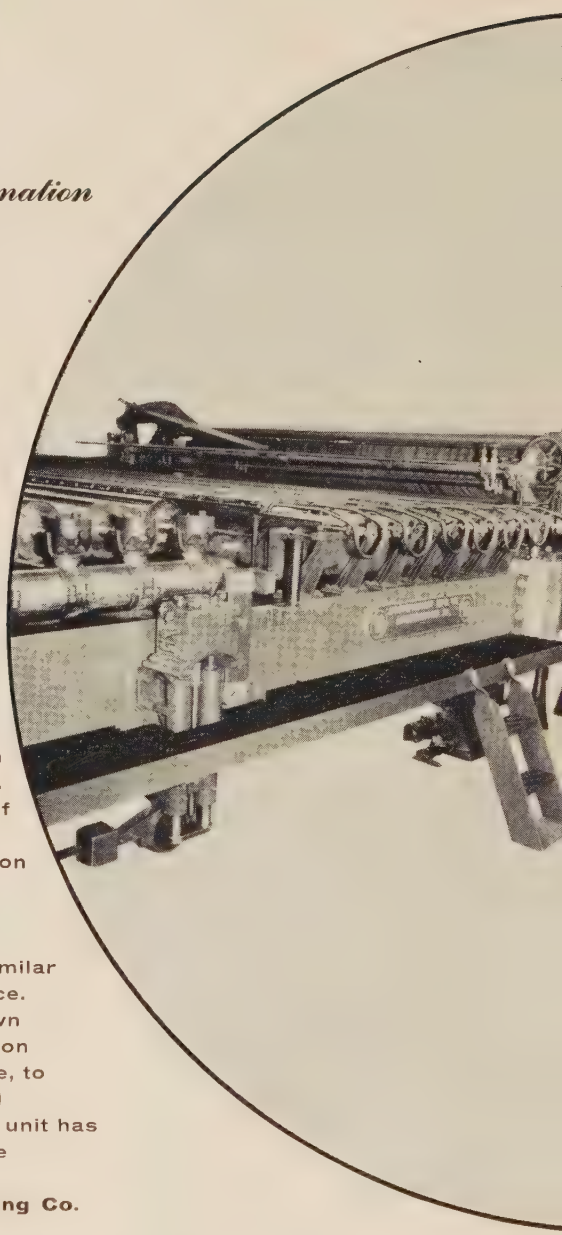

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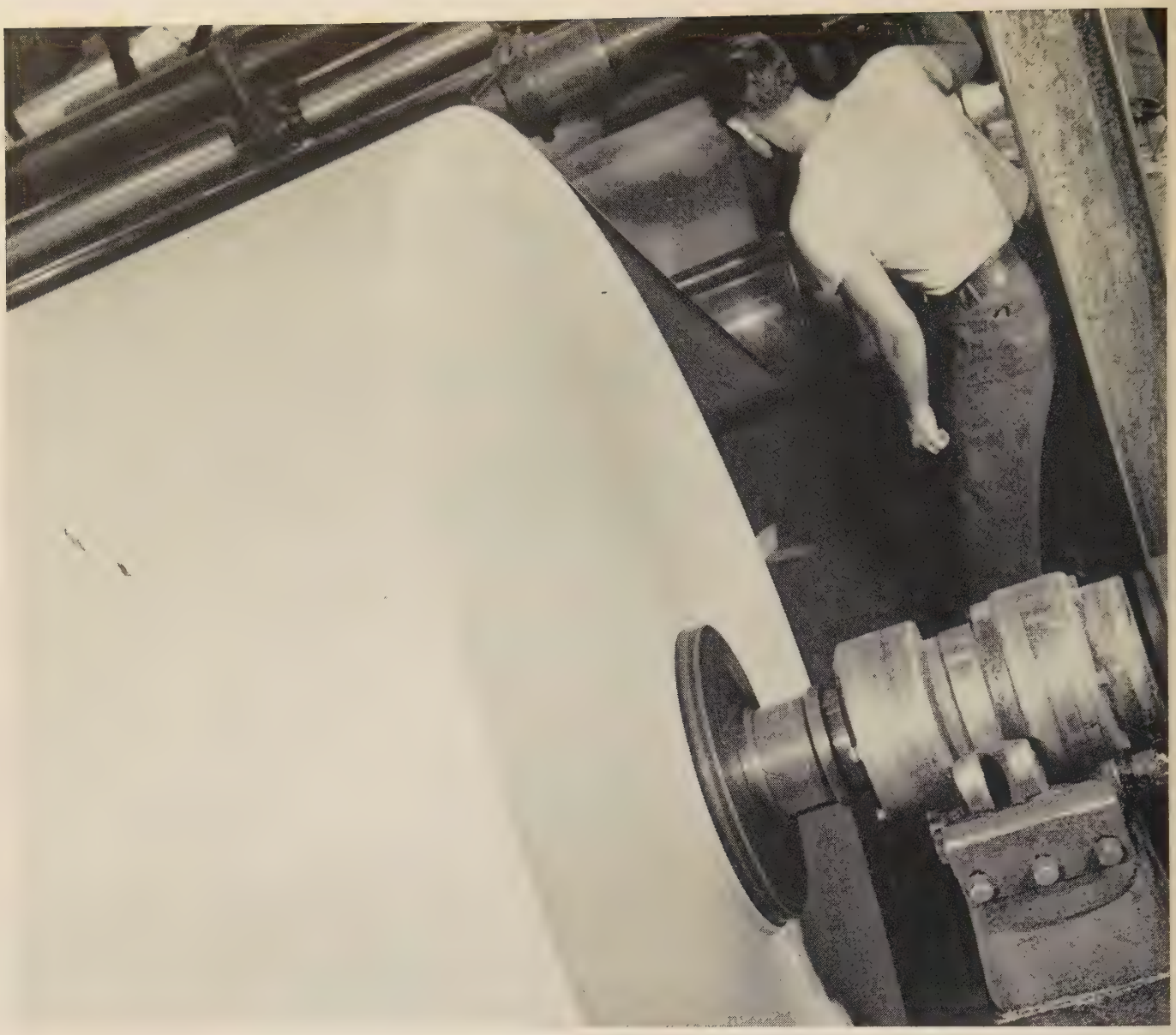

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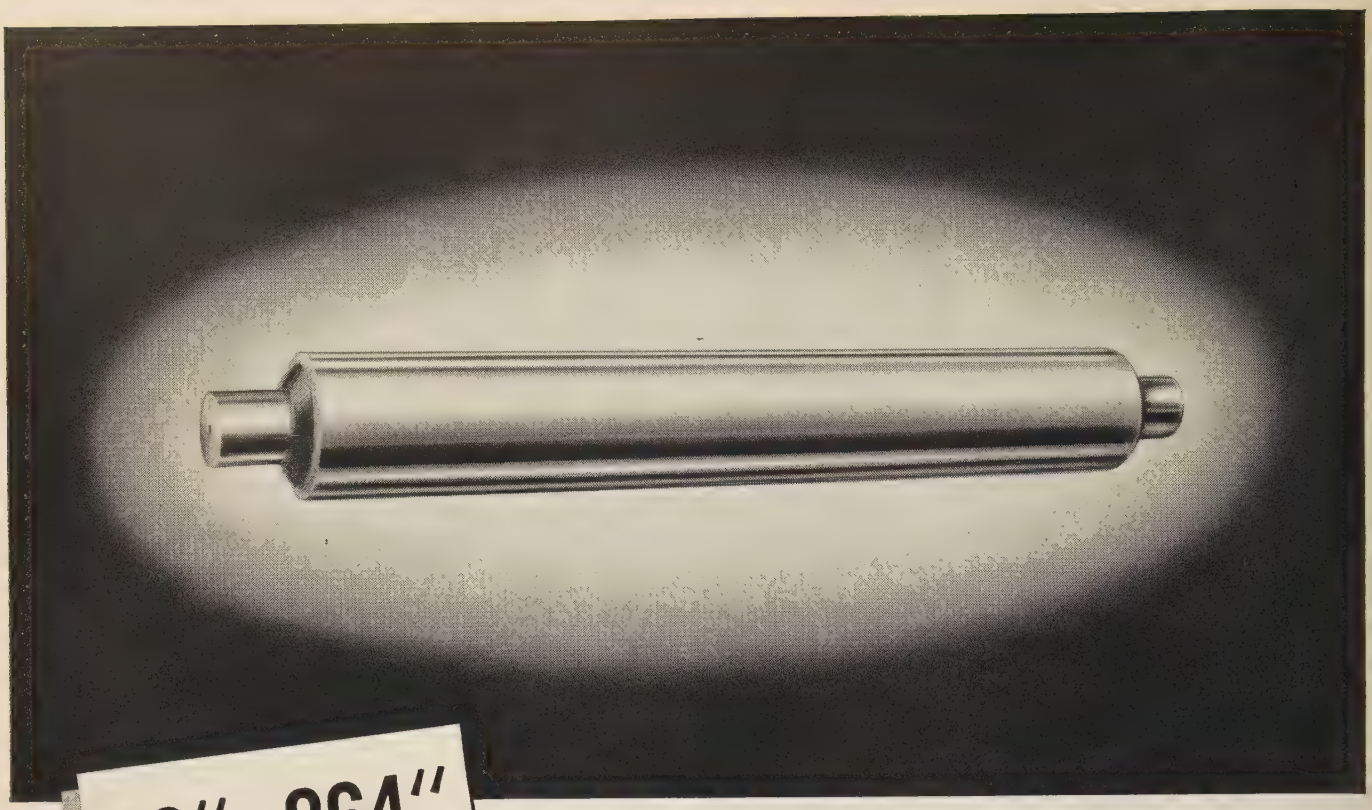

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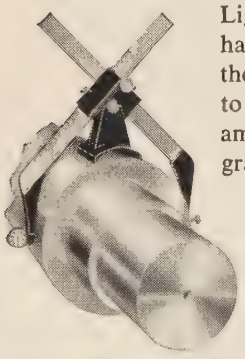

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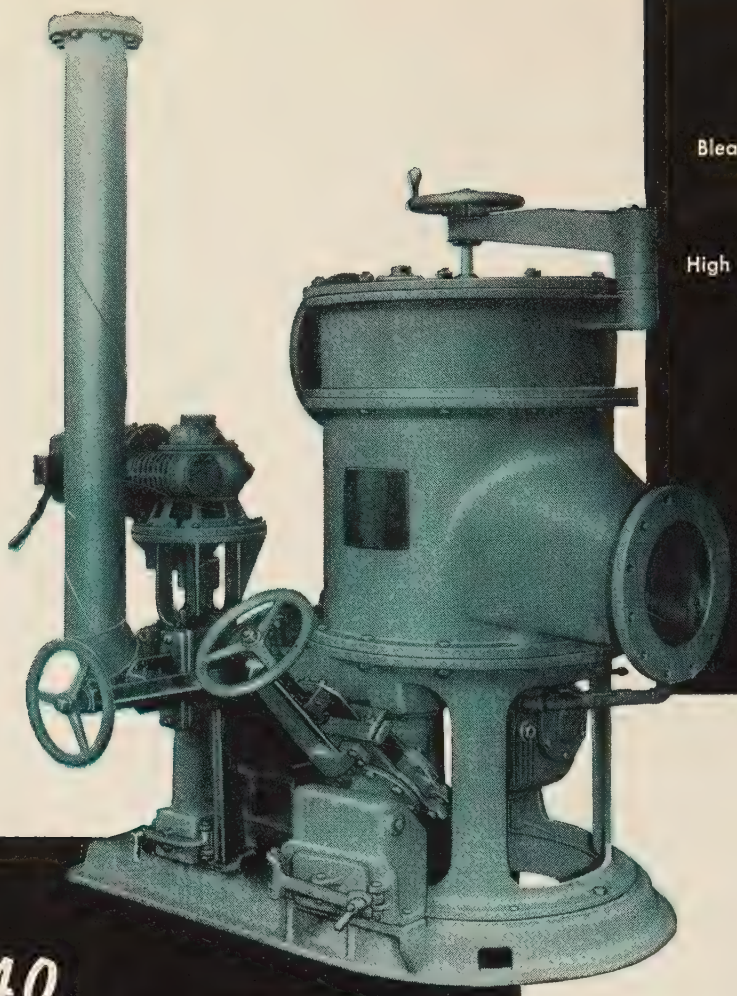

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Semichemical Pulping of Hardwoods with Sodium Sulphite and Sodium Bisulphite—II

R. M. HUSBAND

A new process for preparing bleachable semichemical pulps from hardwoods is described. It employs sodium bisulphite (sodium acid sulphite) solutions buffered within the pH range 3.7 to 5.8 by the sodium acetate-acetic acid system. This buffer system is created from the acetic acid deriving from the wood together with a small amount of sodium ion conveniently provided by sodium sulphite. Accordingly any pH level within the range may be chosen by proportioning sodium sulphite to the "wood acids." It is demonstrated that, at a liquor to wood ratio of 4.7:1, sulphur dioxide in the amount of 5% of the weight of white birch wood can remove 90% or more of the lignin removed by greater proportions. This is true throughout the pH range governed by the sodium acetate-acetic acid buffer system and also in the pH range controlled by the sodium sulphite-sodium bisulphite buffer system. It is demonstrated that semichemical pulps prepared from white birch wood digested at pH 4 with small amounts of sodium bisulphite are not weaker than neutral sulphite semichemical pulps prepared in the same yield from the same wood with much larger proportions of chemicals. An understanding of the chemistry of the neutral sulphite process is provided.

THAT hot solutions of sodium sulphite can extensively delignify many species of wood has been demonstrated by many laboratory and larger scale investigations that followed the patent of Cross and Bevan reported in 1880. And today this chemical has come to commercial importance for the partial delignification of hardwood chips according to the conditions of the neutral sulphite semichemical process. While a generalized explanation of its delignifying action may seem to be implicit in the now well-known pictures of pulping with bisulphites, developed principally by Hägglund and his coworkers (*1*) in Sweden, and Maass, Yorston, and their associates (*2, 3, 4*) in Canada, nevertheless, in the literature of sodium sulphite and neutral sulphite pulping it has either explicitly or implicitly been treated as a distinct and separate reagent (*5–9*). Only recently (*10*) has its behavior been attributed to the bisulphite ions it furnishes when subjected to the organic carboxylic acids provided by the wood.

According to the hypothesis of Hägglund and associates, the lignin polymer of wood when digested with acidic solutions of bisulphites first acquires sulphonic acid groups at a relatively rapid rate and then suffers fragmentation into hydrophilic segments. The rate of removal of lignin from the wood they found to be subordinate only to this latter reaction which they consider to be an acid hydrolysis. Hence, they consider that the removal of lignin at constant temperature is dependent upon the pH of the digesting solution, though the relationship is not direct because the sulphonic acid anions bound to the lignin affect the hydrogen ion concentration within the wood chips or fragments in the general manner described by the membrane equilibrium theory of Donnan.

Maass, Yorston, and their associates hold a different view of these reactions as they apply to the acid sulphite process and have presented repeated evidence that the rate of lignin removal is not strictly governed by the hydrogen ion concentration of the liquor alone but is also subject to the concentration of bisulphite ions.

More recently Häggroth, Lindgren, and Saedén (*11*) have confirmed the view of Maass, *et al.*, by showing that, in the presence of tremendous excesses of cooking liquor, the rate of lignin removal from softwoods at pH levels below 2.4 (measured at room temperature) is subject to the amount of sulphur dioxide applied, in addition to the hydrogen ion concentration. However, they also found that at pH 3.5 (at room temperature) and less acid levels the rate was not so affected by changes in the proportion of sulphur dioxide.

In our previous report on the digestion of hardwood chips with solutions containing sodium sulphite and sodium bisulphite at chemical to wood ratios appropriate to semichemical pulping, it was shown that the removal of lignin was subject to the concentration of bisulphite ions as well as the concentration of hydrogen ions. That study has now been expanded to provide a more detailed picture over a wider range of conditions including those common to the neutral sulphite process.

EXPERIMENTAL

Bark-free white birch logs were cut into $^5/_8$-in. chips in a ten-knife Carthage chipper and screened to remove the fines and over-size pieces. The accepted chips were thoroughly mixed then stored in moisture-proof containers pending use. Samples of the chips were dried in an oven at 105°C. so that the weight of dry wood, charged in any cook, would be known.

The chips were cooked in a stainless steel vertical digester of 1 cu. ft. capacity equipped with an external heat exchanger and circulation system which cycled the liquors at the rate of 2 g.p.m. To facilitate the penetration of the chemicals into the chips, a Nash-Hytor vacuum pump was used to evacuate the digester and charged chips to a gage reading equivalent to 28 to 29 in. of mercury. After this pressure reading had been maintained for 15 min., the liquor was drawn into the digester from a pail, through a rubber tube containing a sight-glass. By adding the liquor in this way less than 50 ml. was excluded when the valve at the digester head was closed as the liquor level fell through the sight-glass, and no air was admitted. The liquor to wood ratio was maintained at 4.67 liters per kg. of oven-dry wood. The charged digester was heated to 100°C. in 15 min. and then to the desired cooking temperature according to a prescribed schedule.

At the conclusion of a cook the chips were thoroughly

R. M. HUSBAND, Research Associate and Project Leader, State University of New York, College of Forestry, Syracuse, N. Y.

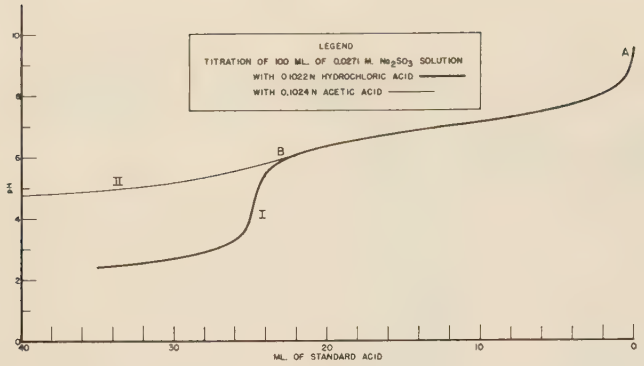

Fig. 1. Courses of pH during the titration of sodium sulphite solutions with hydrochloric and acetic acid solutions

washed in the open digester with hot tap water, then, without delay, pulped in a 12-in. laboratory Sprout-Waldron disintegrator in a full stream of hot tap-water (pH about 8). The pulp was passed through a plate with 0.012-in. slots and if there were any amount of rejects, they were passed through the disintegrator a second time. Excess water was squeezed from the pulp in a fruit press, the cake of pulp weighed, then crumbled and sampled for a moisture determination. The pulp was stored in moistureproof containers.

The cooking liquors were prepared from tap water, C.P. sodium sulphite and C.P. sodium bicarbonate or U.S.P. sodium bisulphite containing 97% of sodium metabisulphite equivalent to 106% of $NaHSO_3$. The sodium sulphite and bisulphite content of fresh liquors was determined iodometrically but their content of sodium bicarbonate was known only from the weight of pure chemical used in their preparation.

During each cook, samples of liquor were withdrawn periodically through a water-cooled condenser. The pH values of these samples were measured at room temperature and their content of reducing chemicals determined iodometrically in an acidic medium.

The strength properties of the pulp were evaluated according to the TAPPI Standard beater test. Pulp brightness values were obtained from handsheets of unbeaten pulp, using a Hunter brightness tester with the tristimulus blue filter.

The amounts of lignin and pentosans in the pulps and the lignin content of the woods were determined according to TAPPI Standard procedures. The pentosan content of the woods was determined according to the TAPPI Standard procedure for pentosans in pulp.

While all of the white birch logs used in this study were of one shipment from the same site in Upper New York State, two different batches of chips are involved having different chemical analysis and providing pulps with somewhat different physical properties. They will be distinguished as wood A and wood B.

	Wood A, %	*Wood B*, %
Alcohol-benzene extractives	2.2	2.0
Tappi lignin-basis unextracted wood	18.3	17.0
Pentosans-basis unextracted wood	23.3	25.0

DISCUSSION OF RESULTS

The Important Role of the Wood Acids

It has already been pointed out that the wood acids play an important role in digestion of hardwood chips with sodium sulphite solutions (*10*); that as they are liberated from the wood they serve to convert increasing proportions of sulphite ions to bisulphite ions which were considered to be the species active in sulphonation. However, the expanded study has shown that they can perform another important function that will be more clearly understood with the aid of the plots of Fig. 1. These plots were obtained by recording the pH value at intervals during the titration of solutions of sodium sulphite with standard acid solutions. Curve I is the familiar plot for sodium sulphite acidified with hydrochloric acid. In effect, it shows the pH values for solutions containing sodium sulphite and sodium bisulphite in every relative proportion at a constant molarity of sulphur dioxide.

When a solution of sodium sulphite in water is applied to hardwood chips and the mixture heated, the pH value of the solution (measured at room temperature) immediately falls along the pathway of plot I from A toward B as the wood acids* are released and increasing amounts of sulphite ion are converted to bisulphite ion according to the expression:

$$Na_2SO_3 + H\ Acetate \rightleftharpoons NaHSO_3 + Na\ Acetate$$

While the decline of pH is initially rapid, its fall is soon checked because sodium bisulphite and sodium sulphite, together in solution, form a buffer system whose capacity to absorb acids continually increases toward pH 7.2 where the ratio of the two components is unity. Furthermore, the decline of pH is opposed by the sulphonation of the lignin which reaction serves to withdraw from solution the acidic salt sodium bisulphite to form

* The organic acids liberated during 4 hr. of digestion of the white birch wood used in this study amount, at 160°C., to about 5.5% of the weight of the wood when expressed in terms of acetic acid which accounts for 99% of them.

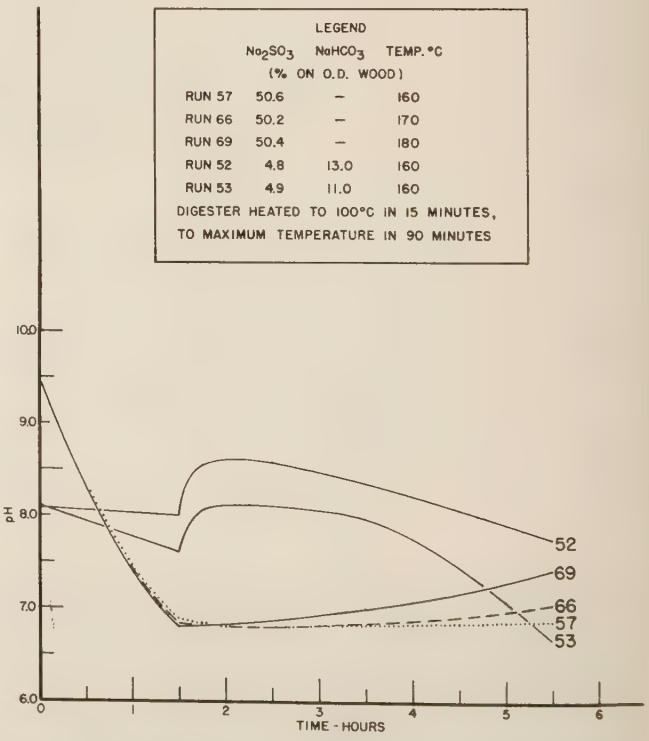

Fig. 2. pH histories during heating and digestion of white birch chips with sodium sulphite–bisulphite solutions

the less acid salt sodium lignin sulphonate.† If the bisulphite ions may be regarded as the active agents of sulphonation, then the onset of that reaction should be marked by their first appearance in solution and its rate and extent should increase as the proportion of bisulphite ions increases.

Whether the pH level of the cooking liquors falls appreciably below the point of maximum buffering depends to a minor extent upon the competing rates of the sulphonation and the removal into solution of fragments of sulphonated lignin, but principally upon the liberation of the wood acids and the proportion of sodium sulphite applied to the wood. When that proportion is large, the wood acids may be absorbed without complete conversion of the sodium sulphite to sodium bisulphite which, in turn, becomes large relative to the amount of sodium bisulphite consumed by sulphonation. Such are the conditions described by those plots of Fig. 2 which show the change of pH with time recorded during the digestion of white birch wood chips with 50% of their weight of sodium sulphite at 160°C. (run no. 57, Table I), 170°C. (run no. 66), and 180°C. (run no. 69). The fact that each of these curves shows a reversion of pH from a minimum was interpreted (*10*) as reflecting that sulphonation opposed the acidifying influence of the wood acids. Hence, the increase in reversion with increasing temperature may be considered indicative of increasing sulphonation.

† The influence of the Donnan equilibrium is neglected here.

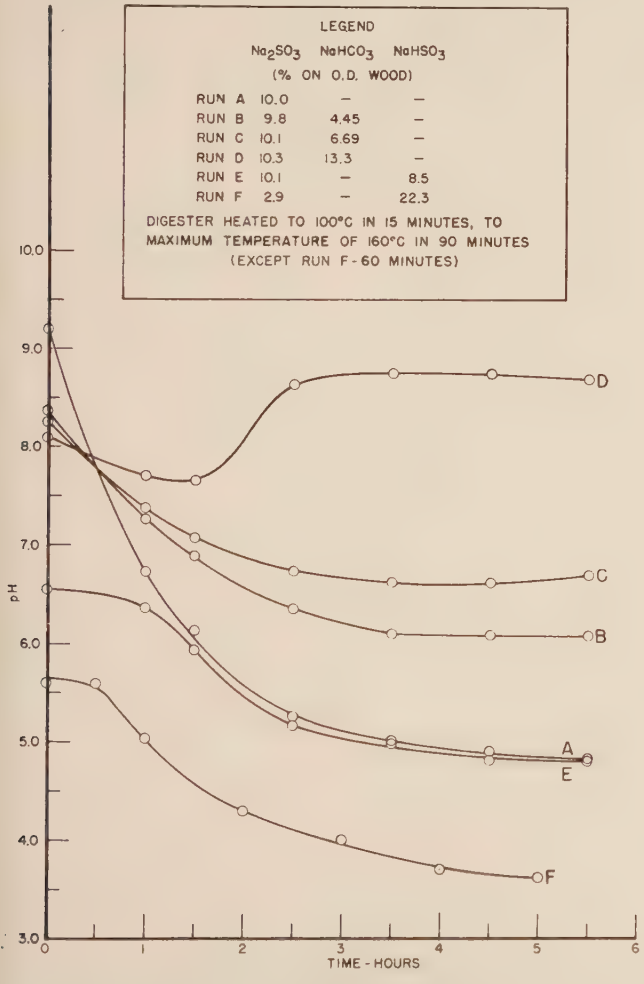

Fig. 3. pH histories during heating and digestion of white birch chips with sodium sulphite–bisulphite solutions

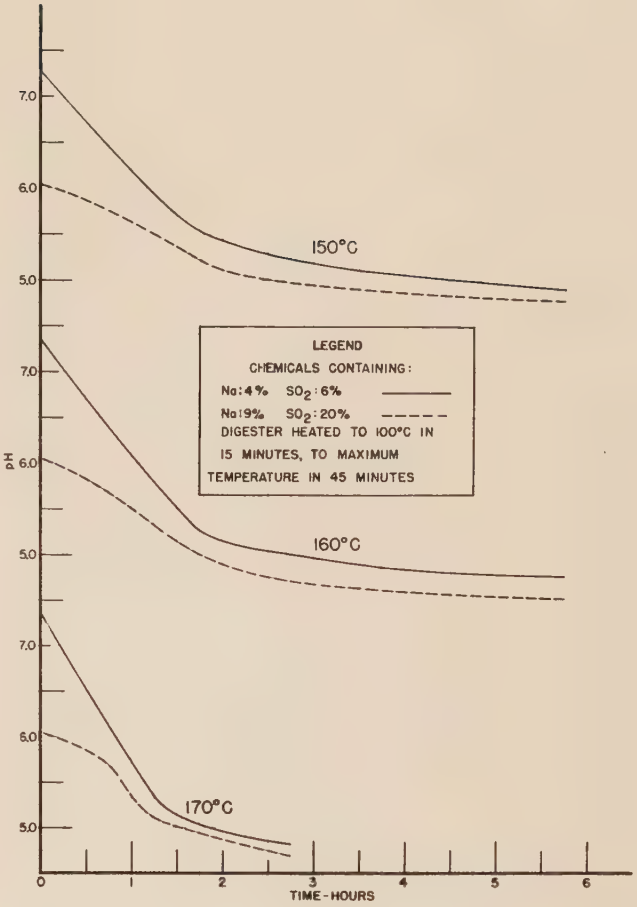

Fig. 4. The variation of pH history in digestions at "pH"

On the other hand, when the amount of sodium sulphite is much smaller relative to the wood and the wood acids, these latter are sufficient in amount and strength to exceed the buffer capacity of the bisulphite-sulphite system. From curve I of Fig. 1 it might be expected that if these quantities were so related that the liquors could be acidified to pH levels about 6, without exhaustion of the wood acids, the sulphite-bisulphite buffer system should be essentially destroyed and there should be no barrier to an extensive drop in pH. However, in Fig. 3, the plot for run A (as well as the course of pH values previously recorded (*10*)) shows that with white birch wood and about 10% of sodium sulphite, the liquors were acidified to the vicinity of pH 6 about the time that the maximum temperature of digestion was reached. Thereafter, the pH values decreased more slowly and became relatively constant within the range pH 5.2 to 4.8 during 3 or more hours of subsequent cooking.

This phenomenon may be explained by the fact that the cooking liquors had come to be buffered by the sodium acetate-acetic acid buffer system. From the inception of cooking, the liberation of the wood acids, in which acetic acid preponderates, serves to provide from the sodium sulphite equivalent amounts of sodium bisulphite and sodium acetate according to the foregoing equation. While the bisulphite may be largely consumed in reaction with lignin, the sodium acetate accumulates in the liquors. If the number of moles of acetic acid coming into solution exceeds the number of moles of sodium sulphite, then that equilibrium must be displaced far to the right and any

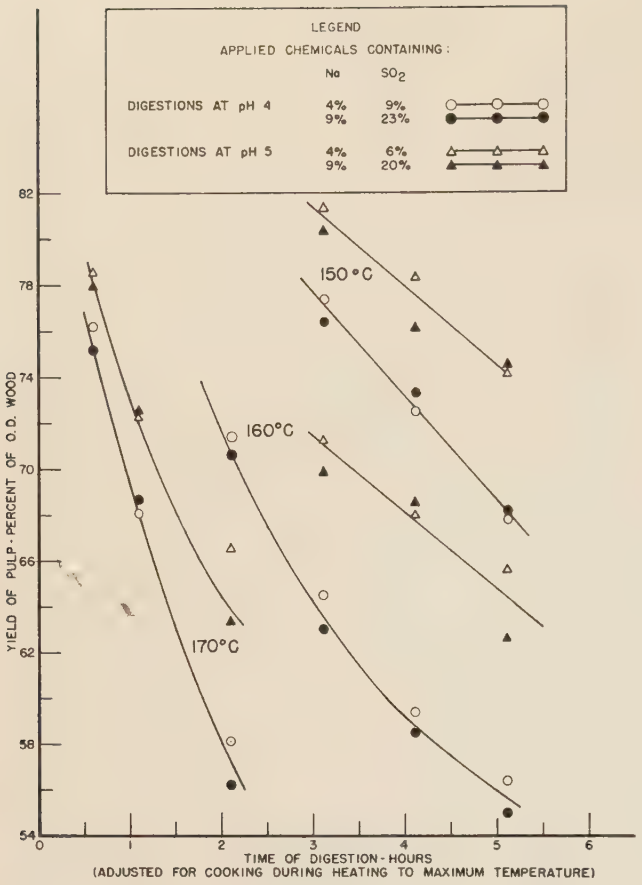

Fig. 5. Yield of pulp versus time of digestion at pH 4 and at pH 5

excess of acetic acid will serve to create, with the sodium acetate, a buffer system of continually increasing capacity to the point where the amount of acetic acid is equivalent to the amount of sodium acetate—about pH 4.75.

Curve II of Fig. 1 was obtained by titrating a solution of sodium sulphite with acetic acid to illustrate the buffering action of the acetic acid-sodium acetate system in the extreme case where none of the bisulphite is consumed. There is also to be observed the fact that the pH value of sodium bisulphite solutions (which vary with dilution between 4.8 at 4% by weight and 4.2 at 0.3% by weight) fall into the range of values covered by that buffer system (*ca.* 3.7 to 5.7). This means that hardwood may be digested with any desirable proportion of sodium bisulphite at any pH level between, say, 3.7 and 5.7 chosen by proportioning an additional small amount of sodium sulphite (or additional base) to the wood acids. And since the sodium acetate-acetic acid and sodium sulphite-bisulphite buffer systems blend together without significant discontinuity, it is further evident that any amount of bisulphite ion may be conveniently applied to white birch chips at any pH level in the wider range between 4 and 8 chosen by proportioning additional sodium base to the wood acids.

The particular importance of this understanding lies in the previous finding (*10*) that, at least within the range of pH 3.5 to 7, the removal of lignin from white birch wood at constant pH, temperature, and time, was subject to the concentration of bisulphite ions whereas the hydrolysis of the carbohydrate components of the wood was not. Hence, conditions have been realized that allow the digestion of wood over a wide range of hydrolytic conditions to determine, at each chosen condition, a minimum proportion of sulphur dioxide necessary to remove a practical maximum of lignin. And, since pulp strength properties vary with hydrolytic conditions, it should be possible to arrange experiments to reveal the influence of hydrolytic conditions upon pulp strength properties at a fixed content of lignin.

The Influence of Sodium Bicarbonate and Other Alkaline Salts Upon the Course of pH During Digestion with Sodium Bisulphite

This study, like much of the present day industrial processing, has been based upon batch processing of chips without any addition or withdrawal of chemical components during digestion. Consequently, it has importance to discuss here the diverse courses of pH change that accompany the application of different amounts of sodium sulphite together with sodium bicarbonate, sodium bisulphite, sodium hydroxide, or sodium carbonate, as they may be apportioned to affect digestion at some chosen pH level within the wide range that has been shown to be governed by the acetate-acetic acid and sulphite-bisulphite buffer systems.

It has already been shown that, when white birch wood is heated with 50% of its weight of sodium sulphite, the acids diffusing from the chips can acidify the sulphite solution from its initial value of pH 9.5 to the realm of pH 7 by the time the digesting temperature is reached, and that the digestive liquors are subsequently buffered in the range 6.7 to 7.4. When smaller amounts

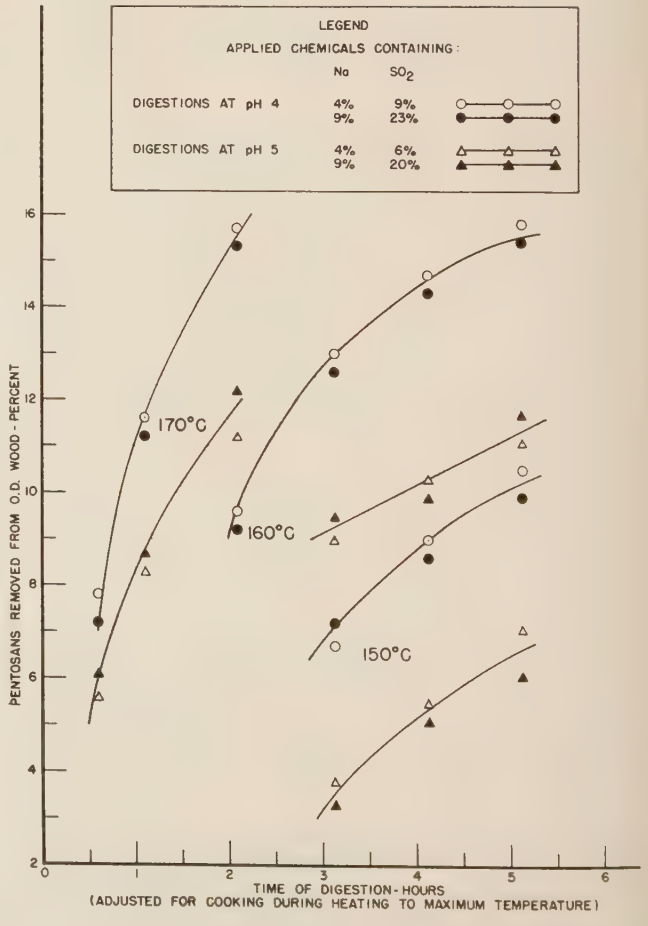

Fig. 6. Pentasan removal versus time of digestion at pH 4 and at pH 5

of sodium sulphite are applied to the wood, the course of pH falls from about the same initial level (the pH of sodium sulphite solutions vary with dilution) to pH levels below 7, but during the digestion at maximum temperature the liquors are still buffered by one or other of the two buffer systems. Thus, when 10% of sodium sulphite is used, the great part of the period of digestion at maximum temperature is spent in the neighborhood of pH 5.

Now the wood may be subjected to less than 50% of sodium sulphite and the digestion conducted in liquors of pH 7, or higher, if additional alkaline base is added to offset some of the wood acids and thus prevent complete or very extensive conversion of sulphite to bisulphite. When the added base is sodium bicarbonate, the pH values of the initial liquors fall further toward pH 8 as more bicarbonate is added (see Fig. 3) since sodium bicarbonate is a less alkaline salt than sodium sulphite. Upon heating such solutions in mixtures with wood, the acids from the wood change some of the sodium bicarbonate to carbonic acid and so create the carbonic acid-sodium bicarbonate buffer system which then is part of the restraint upon pH change until the digester is relieved of carbon dioxide—in this study, as soon as the maximum temperature was reached; but with the removal of the carbon dioxide, the control of pH depends upon the sulphite-bisulphite buffer system. The course of pH changes accompanying digestions with such mixtures is shown by the plots for runs B and C in Fig. 3. If a very large proportion of bicarbonate is used, then, upon relief of the carbon dioxide, the pH may increase (see run D) to the level where the solution is affected by the sodium carbonate-bicarbonate system. Under such conditions, retention of the carbon

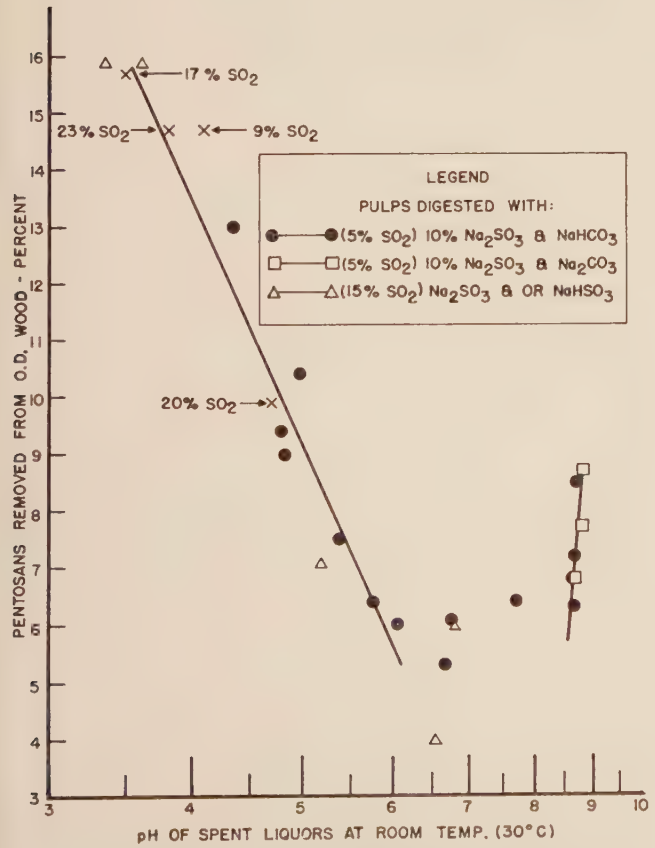
17 % SO2
23% SO2
9% SO2
20% SO2
LEGEND
PULPS DIGESTED WITH:
(5% SO2) 10% Na2SO3 & NaHCO3
(5% SO2) 10% Na2SO3 & Na2CO3
(15% SO2) Na2SO3 & OR NaHSO3
PENTOSANS REMOVED FROM O.D. WOOD - PERCENT
pH OF SPENT LIQUORS AT ROOM TEMP. (30°C)

Fig. 7. Semilogarithmic plot of pentosan removal versus pH

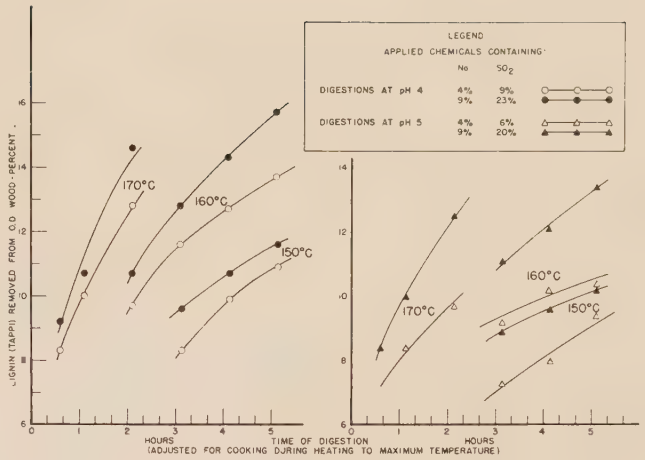

Fig. 8. Lignin removal versus time of digestion at pH 4 and at pH 5

dioxide would allow a less alkaline digestion and often a brighter pulp.

The two curves of Fig. 2 labelled run no. 52 and run no. 53 reflect the course of pH during digestions with large portions of sodium bicarbonate accompanied by a very small proportion of sodium sulphite (5%). They show a rapid rise in pH accompanying relief of the carbon dioxide at the time when the maximum temperature was reached. Thereafter, the pH values fell through the upper range of the sulphite-bisulphite system which was too small in amount to hold the pH within a small range of values for any length of time during the cook although the one experiment was concluded about pH 7. In these experiments, the total amounts of applied chemicals were too small relative to the wood acids to allow establishment of the carbonate-bicarbonate buffer system as just described.

The above considerations make it clear that, despite all contrary statements in the literature, sodium bicarbonate is not truly the buffer in the usual application of the neutral sulphite process. It is, rather, used as a source of bicarbonate ions to accept protons from the wood acids and so to adjust the pH level of the sulphite-bisulphite buffer system. And this explanation does not allow it any pulping role.

In like fashion, sodium carbonate or sodium hydroxide may be used as sources of ions to counteract the wood acids and to adjust the sulphite-bisulphite buffer system. They make the initial sodium sulphite solutions more alkaline but they can display their separate influence upon a digestion only during the period of time required for the wood acids to acidify the liquors into the range of the sulphite-bisulphite system. The greater the ratio of the soda ash or caustic to the sodium sulphite, and the greater the proportion of total chemicals to the wood, the longer is that period of alkaline digestion.

To effect digestion at pH 5, about 10% of sodium sulphite must be applied to white birch wood and still smaller amounts must be used to reach lower pH levels. Nevertheless, at any such pH level within the range of the acetate buffer system, any desirable proportion of bisulphite ion may be applied by adding sodium bisulphite as part of the fresh liquors. Such additions make the liquors more acid during the period of heating to maximum temperature but it is clear, from Fig. 3 (runs A and E) and Fig. 4, that they affect the acetate buffer

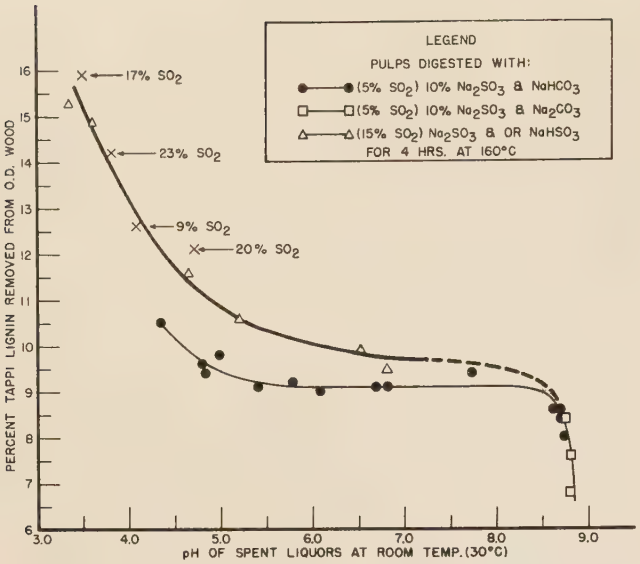
LEGEND
PULPS DIGESTED WITH:
(5% SO2) 10% Na2SO3 & NaHCO3
(5% SO2) 10% Na2SO3 & Na2CO3
(15% SO2) Na2SO3 & OR NaHSO3
FOR 4 HRS. AT 160°C
17% SO2
23% SO2
9% SO2
20% SO2
PERCENT TAPPI LIGNIN REMOVED FROM O.D. WOOD
pH OF SPENT LIQUORS AT ROOM TEMP.(30°C)

Fig. 9. Lignin removal versus pH of the spent liquors

system very little and so scarcely alter the pH level of digestion established by the proportion of sodium sulphite.

In Fig. 3, the curve for run F shows the course of pH during heating and digestion with 3% of sodium sulphite and 22% of sodium bisulphite in the lower range of the acetate buffer system. Such a digestion provided, at the end of 4 hr. at 160°C., a 56% yield of pulp containing 5.4% of lignin. Similar yields of pulps, containing slightly less lignin, can be obtained in digestions with slightly less sodium base and during which the acetate-acetic acid buffer system serves to restrain the decline of pH throughout the great part of the period of digestion.

Precision of pH Control

In the experiments that form the basis for the subsequent discussion, white birch wood was digested at "pH 4," "pH 5," and "pH 7" with different proportions of sulphur dioxide by adjusting the proportions of the applied chemicals, sodium sulphite, sodium bisulphite, and sodium bicarbonate. From the preceding discussion it is clear that in no case was the pH constant throughout the period of heating and digestion.

The curves of Fig. 4 show the courses of pH during digestions at "pH 5" which were effected by using 10% of sodium sulphite together with 1.5 or 24.5% of sodium bisulphite. While the initial pH values differ appreciably with the proportion of bisulphite, it is clear that during the period of digestion at maximum temperature the two sets of experiments differed by less than 0.3 pH units. Of course, the plots for the period of digestion could be brought into coincidence by more precise proportioning of the sodium to the sulphur dioxide and the wood acids.

At any temperature and with a chosen proportion of sulphur dioxide to base, digestions of differing duration followed almost exactly the same course of pH which fell to progressively lower levels as the period of digestion was extended. Thus, at 150°C. with 10% of Na_2SO_3 and 1.5% of $NaHSO_3$ (the uppermost curve), a cook of 3 hr. duration concluded at pH 5.1; one of 4 hr. duration at pH 5.0; and one of 5 hr. duration at pH 4.9. It would, of course, be possible to proportion the chemicals so that each digestion was concluded at the same value, regardless of time, but then each cook would of necessity follow a slightly different course. As it stands, the differences in final pH level, resulting from different times of digestion, are slight.

A greater difference results from changes in temperature which affect the rate of acidification, by the wood acids, of the solution external to the chips. For example, digestions made with 10% of Na_2SO_3 together with 1.5% of $NaHSO_3$ had, at the end of 2 hr. at maximum temperature, pH values (Fig. 4) of 5.2 at 150°C.; 5.0 at 160°C.; and 4.8 at 170°C.

Combining these several variations deriving from changes in time, temperature, and chemical proportion, it may be said that the digestions at "pH 4" were confined to the range between 3.8 and 4.5 (and these two extreme values pertain to cooking at the highest temperature, 170°C.); the digestions at "pH 5" to the range between pH 4.6 and pH 5.2; and the digestions at "pH 7" between a minimum of 6.7 and a maximum of 7.4.

The Removal of Lignin and Pentosans from White Birch Wood

Two series of experiments were made at pH 4 and 150, 160, and 170°C. with mixtures of sodium sulphite and sodium bisulphite containing 9 and 23% of sulphur dioxide on the basis of the dry wood. Two other such series were made at pH 5 with the same proportions of sodium (4 and 9%), hence with 6 and 20% of sulphur dioxide, while in a series of comparative neutral sulphite digestions the greater amount of sodium was applied and this choice dictated the application of 11% of sulphur dioxide. Despite the fact that 23 and 20% of sulphur dioxide are impractically large amounts for semichemical pulping, they were chosen to establish the contribution of such excesses.

The plots of Fig. 5 show the rates of decline of pulp

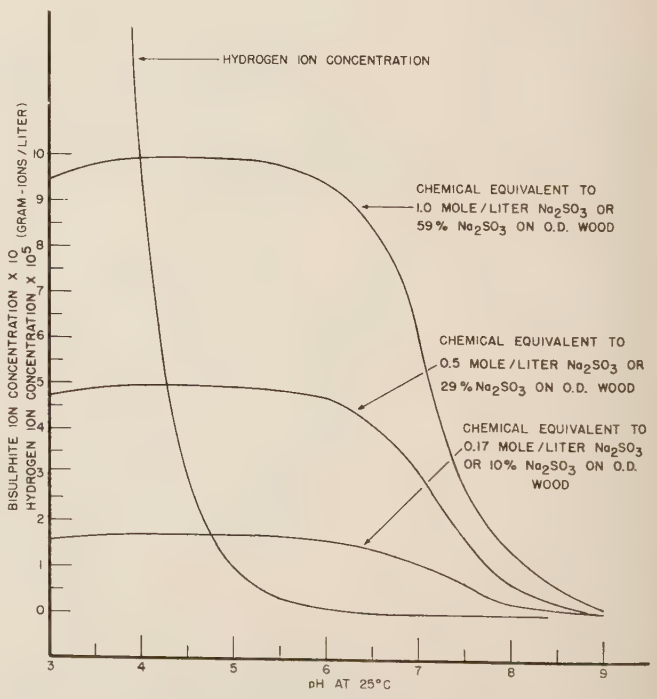

Fig. 10. Bisulphite ion concentration and hydrogen ion concentration versus pH of sodium sulphite–bisulphite solutions at 25°C.

yield at pH 4 and pH 5 between 150 and 170°C., and that the yield of pulp is not significantly affected by the proportion of bisulphite ion applied, time, temperature, and pH being constant. At pH 7, the rate of decline of pulp yield (not plotted—see Tables I and II, runs no. 45 to 50) is more gentle at corresponding temperatures and again not influenced by the proportion of bisulphite ion as the data for runs no. 52 to 66 show. Likewise the plots of Fig. 6 show the removal of the pentosans to be related to pH, time, and temperature, but not significantly affected by variation in the concentration of bisulphite at pH 4 or pH 5. The data for runs no. 60, 61, and 62 confirm this conclusion for digestions at pH 7. However, the data for runs no. 63 to 66 suggest that at pH 7 and higher temperatures the removal of pentosans diminishes as the concentrations of applied chemicals increases. Presumably this decrease is related to a "salting out" effect, and/or the changing Donnan equilibrium.

The influence of hydrogen-ion concentration upon the removal of pentosans, at fixed time and temperature, is shown in the semilogarithmic plot of Fig. 7 which includes data not otherwise presented in this report. It is to be noted that the pH values of the waste liquors are used in this figure. Since the pH values varied during each experiment, as has been explained, the plotted points are somewhat scattered.

The removal of lignin from the wood is subject to all the variables that affect the pentosans and in addition to the concentration of applied bisulphite, as the plots

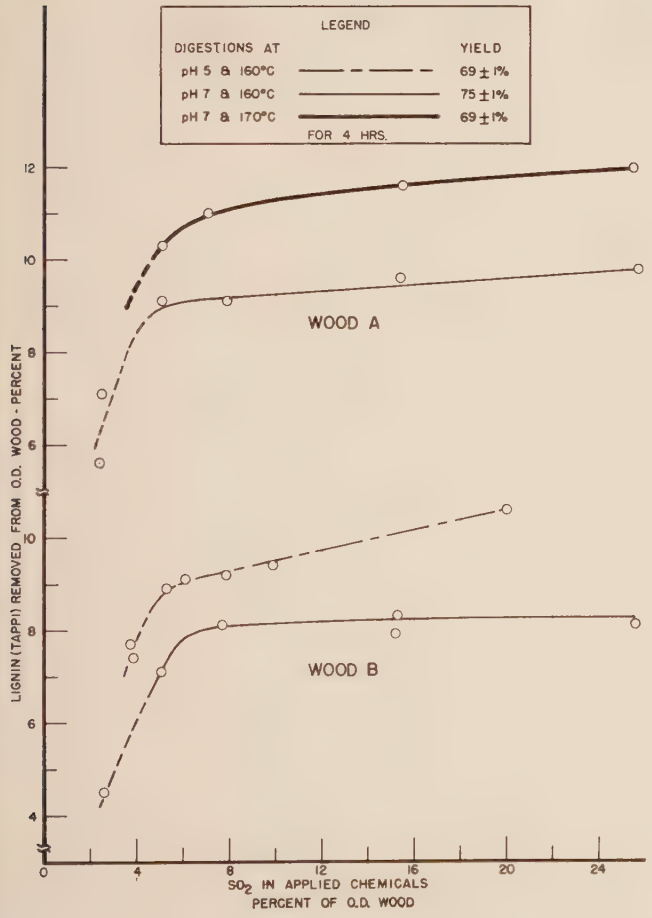

Fig. 11. Influence of bisulphite ion concentration upon lignin removal at fixed pH, constant temperature and digestion time

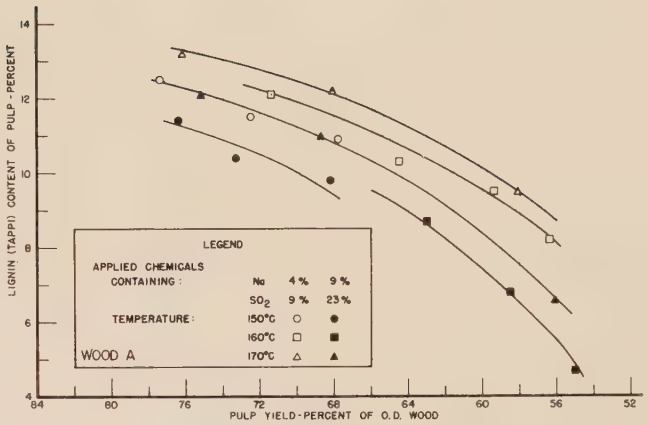

Fig. 12. Lignin contents of various pulps digested at pH 4

of Fig. 8 demonstrate. The influence of hydrogen ion and bisulphite ion concentration at fixed time and temperature are shown in Fig. 9 which also includes data not otherwise presented in this report. In this latter figure, it is to be observed that the shapes of the curves for lignin removal qualitatively reflect both changing hydrogen ion concentration and changing bisulphite ion concentration which are mapped in Fig. 10. The extreme right hand portions of these curves reveal that lignin removal falls off markedly above pH 8 as the concentration of bisulphite ions falls to insignificance. Since the sulphite ion concentration increases there correspondingly, these data would seem to preclude the sulphite ion as a sulphonating agent in this pH range. Otherwise, it must be assumed that alkaline rearrangement of some part of the lignin has effectively prohibited its removal by the mechanisms pertaining at lower pH levels. The curve representing the application of 5% of SO_2 terminates short of pH 4, because the consumption of bisulphite from liquors held for 4 hr. at 160°C. and pH 4, or less, is greater than the amount provided by 5% of SO_2. Hence, lignin removal with 5% of SO_2 is limited at lower pH levels by inadequate sulphonation and "burning," as was previously demonstrated (*10*). The curve corresponding to 15% of SO_2 would presumably rise more steeply at its acid end if, in that region, the amount of applied bisulphite was not diminished by the dissociation of sulphurous acid and volatilization of some sulphur dioxide. Within the range of present interest, between pH 4 and pH 8, it is apparent that the amounts of lignin removed with increasing proportions of sulphur dioxide are somewhat greater as the hydrogen ion concentration increases. However, it must also be observed that, at any pH level, this gain is quite disproportionate to the increase in applied chemicals whence arises need to define, for practical semichemical pulping, a minimum chemical proportion of maximum efficiency in removing lignin.

Such definition is provided by Fig. 11 in which each curve represents a series of digestions to constant yield. Within each series, the liquor to wood ratio was fixed at 4.67 liters per kg. and the time of digestion at 4 hr. The pH histories within each series were also relatively constant, as has been explained, with the exception of the experiments employing about 2.5% of SO_2 at "pH 7." In these digestions the course of pH could not be confined to the same narrow limits because of

Table I. Cooking Conditions

Run no.[a]	Cooking conditions: Max. temp., °C.,[b]	Time at max. temp., hr.	Chemicals added, % of o.d. wood: Na_2SO_3	$NaHSO_3$	$NaHCO_3$	pH history: pH at 0	pH at max. temp.	pH after digestion at max. temp. for 0.5 hours	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	Residual chemical, g./l. as SO_2
1	150	3	4.1	11.3	...	6.10	5.78	...	4.83	4.60	4.41	...	...	...	12.6
2	150	4	4.0	11.4	...	6.13	5.76	...	4.87	4.57	4.41	4.30	...	...	11.1
3	150	5	3.9	11.3	...	6.11	5.72	...	4.83	4.60	4.41	4.29	4.23	...	9.2
4	160	2	3.9	11.2	...	6.13	5.53	...	4.57	4.31	...	...	...	...	10.8
5	160	3	3.9	11.3	...	6.11	...	...	4.51	4.26	4.13	...	...	...	7.2
6	160	4	4.0	11.3	...	6.12	5.51	...	4.59	4.31	4.15	4.09	...	...	5.2
7	160	5	4.0	11.2	...	6.12	5.49	...	4.59	4.30	4.13	4.03	4.01	...	3.3
8	170	0.5	3.7	11.5	...	6.11	5.06	4.50	...	...	...	...	...	...	13.2
9	170	1	4.0	11.4	...	6.12	5.30	...	4.28	...	...	...	...	...	10.4
10	170	2	4.0	11.3	...	6.11	5.33	...	4.30	4.06	...	...	...	...	4.6
11	150	3	4.0	33.8	...	5.47	5.27	...	4.63	4.43	4.30	...	...	...	39.4
12	150	4	3.9	34.3	...	5.50	5.21	...	4.61	4.46	4.30	4.20	...	...	37.8
13	150	5	4.0	34.3	...	5.48	5.20	...	4.61	4.33	4.16	4.14	4.07	...	34.9
14	160	2	3.8	33.8	...	5.51	5.11	...	4.46	4.23	...	...	...	...	36.3
15	160	3	4.1	33.8	...	5.51	5.10	...	4.42	4.14	4.00	...	...	...	31.5
16	160	4	4.1	34.1	...	5.47	5.18	...	4.40	4.16	3.97	3.82	...	...	25.9
17	160	5	4.0	34.0	...	5.49	5.11	...	4.42	4.16	3.96	3.81	3.71	...	20.2
18	170	0.5	4.0	34.8	...	5.43	5.02	4.38	...	...	...	...	...	...	44.6
19	170	1	3.9	34.3	...	5.51	5.03	...	4.17	...	...	...	...	...	35.6
20	170	2	4.1	34.3	...	5.51	5.01	...	4.17	3.80	...	...	...	...	24.0
21	150	3	10.2	1.5	...	7.37	6.54	...	5.60	5.27	5.11	...	...	...	8.2
22	150	4	10.0	1.5	...	7.34	6.48	...	5.52	5.20	5.09	5.00	...	...	7.1
23	150	5	9.9	1.6	...	7.37	6.43	...	5.51	5.20	5.11	5.00	4.91	...	6.4
24	160	3	10.3	1.5	...	7.34	6.40	...	5.26	5.04	4.90	...	...	...	5.3
25	160	4	9.8	1.6	...	7.37	6.28	...	5.21	5.00	4.90	4.79	...	...	3.9
26	160	5	10.3	1.6	...	7.34	6.40	...	5.30	4.98	4.83	4.81	4.77	...	3.4
27*	160	5	10.2	1.5	...	7.38	6.37	...	5.17	4.93	4.85	4.78	4.74	...	2.8
28	170	0.5	10.3	1.5	...	7.32	6.20	5.31	...	...	...	...	...	...	9.0
29*	170	0.5	10.2	1.6	...	7.34	6.17	5.24	...	...	...	...	...	...	9.7
30	170	1	10.3	1.5	...	7.36	6.17	...	5.04	...	...	...	...	...	6.9
31	170	2	10.0	1.6	...	7.37	6.20	...	5.02	4.83	...	...	...	...	3.6
32*	170	2	10.2	1.6	...	7.34	6.13	...	4.94	4.77	...	...	...	...	3.7
33	150	3	9.7	24.4	...	6.07	5.70	....	5.19	4.96	4.89	...	...	...	36.0
34*	150	3	10.4	24.7	...	6.04	5.81	...	5.22	5.02	4.92	...	...	...	37.0
35	150	4	10.1	24.4	...	6.01	5.80	...	5.27	5.02	4.91	4.82	...	...	34.0
36*	150	4	10.2	24.5	...	6.08	5.77	...	5.25	4.97	4.82	4.74	...	...	32.5
37	150	5	10.0	24.4	...	6.03	5.80	...	5.30	4.97	4.88	4.84	4.79	...	33.5
38*	150	5	10.3	24.5	...	6.05	5.80	...	5.24	5.04	4.82	4.72	4.68	...	33.4
39	160	3	9.4	24.5	...	6.07	5.70	...	5.00	4.70	4.61	...	...	...	30.8
40	160	4	10.2	24.5	...	6.04	5.69	...	5.00	4.83	4.58	4.70	...	...	27.6
41	160	5	10.3	24.5	...	6.05	5.71	...	5.00	4.72	4.62	4.57	4.51	...	23.6
42	170	0.5	9.6	24.3	...	6.07	5.72	5.10	...	...	...	...	...	...	37.0
43	170	1	10.1	24.4	...	6.07	5.71	...	4.92	...	...	...	...	...	33.5
44	170	2	10.1	24.3	...	6.04	5.70	...	4.96	4.70	...	...	...	...	25.6
45*	160	2	21.0	...	4.8	8.29	7.11	...	6.80	6.70	....	...	...	...	16.2
46*	160	4	21.2	...	4.8	8.38	7.12	...	6.83	6.78	6.82	6.83	...	...	14.4
47*	160	6	21.2	...	4.8	8.38	7.13	...	6.82	6.75	6.77	6.77	6.83	6.86	13.2
48*	180	0.5	20.9	...	4.8	8.36	6.81	6.85	...	...	...	...	...	...	13.2
49*	180	1	21.0	...	4.8	8.36	6.92	...	6.84	...	...	...	...	...	12.7
50*	180	2	21.0	...	4.8	8.40	6.90	...	6.88	7.07	...	...	...	...	8.9
51*	188–190	0.25	20.9	...	4.8	8.32	6.89	6.98	(at 15 min.—waste liquor)				...	...	11.8
52	160	4	4.8	...	13.0	8.09	8.00	...	8.59	8.23	8.10	7.76	...	...	2.6
53	160	4	4.9	...	11.0	8.10	7.61	....	8.11	7.99	7.40	6.68	...	...	2.1
54	160	4	10.0	...	7.5	8.17	7.10	...	6.90	6.80	6.80	6.82	...	...	4.6
55	160	4	15.5	...	6.0	8.26	7.01	...	6.94	6.90	6.92	6.97	...	...	8.5
56*	160	4	30.2	...	3.0	8.49	6.84	...	6.68	6.70	6.73	6.77	...	...	22.8
57	160	4	50.6	...	...	9.43	6.89	...	6.80	6.86	6.85	6.87	...	...	42.5
58*	160	4	5.1	...	11.0	8.08	7.72	...	7.98	7.24	6.36	6.04	...	...	2.2
59*	160	4	10.0	...	7.5	8.20	7.40	...	6.92	6.67	6.66	6.67	...	...	3.9
60*	160	4	15.1	...	6.0	8.23	7.16	...	6.78	6.72	6.66	6.76	...	...	8.8
61*	160	4	30.0	...	3.0	8.41	6.93	...	6.70	6.70	6.72	6.76	...	...	22.6
62*	160	4	50.3	...	...	9.55	6.62	...	6.40	6.77	6.82	6.82	...	...	42.2
63	170	4	10.1	...	7.5	8.16	6.99	...	6.87	6.87	6.99	6.71	...	...	2.1
64	170	4	14.0	...	6.0	8.32	6.91	...	6.70	6.86	6.91	6.90	...	...	5.3
65	170	4	30.5	...	3.0	8.41	6.81	...	6.73	6.83	6.90	6.92	...	...	19.8
66	170	4	50.2	...	...	9.42	6.84	...	6.80	6.87	6.90	7.03	...	...	35.7
67	180	4	15.4	...	6.0	8.24	6.79	...	6.78	6.96	7.30	6.94	...	....	2.7
68	180	4	30.1	...	3.0	8.47	6.70	...	6.76	6.92	7.17	7.43	...	...	11.3
69	180	4	50.4	...	...	9.43	6.80	...	6.83	7.02	7.15	7.43	...	...	25.1
70*	160	4	7.3	...	2.5	8.44	6.81	...	5.48	5.16	5.03	4.95	...	...	1.6
71*	160	4	7.6	...	3.1	8.42	6.91	...	5.67	5.31	5.18	5.12	...	...	2.0
72*	160	4	10.5	...	...	9.23	6.43	...	5.24	5.04	4.93	4.88	...	...	3.4
73*	160	4	9.9	1.7	...	7.37	6.26	...	5.18	4.96	4.82	4.74	...	...	4.2
74*	160	4	10.3	4.3	...	6.90	6.33	...	5.32	5.05	5.02	4.98	...	...	6.4
75*	160	4	11.2	6.9	...	6.68	6.21	...	5.37	5.08	4.96	4.88	...	...	11.0
76*	160	4	11.4	13.2	...	6.38	5.93	...	5.27	5.00	4.84	4.83	...	...	18.0
77*	160	4	13.7	21.3	...	6.18	5.88	...	5.32	5.10	5.02	4.96	...	...	29.2

[a] The experiments marked with the asterisk were made upon wood B and all others upon wood A.
[b] Digester heated to maximum temperature in 45 min. in all experiments except: run 51—60 min.; runs 52 to 57 and 63 to 69, inclusive—90 min.

Table II. Chemical Analysis and Physical Properties of the Pulps

Run no.[a]	Pulp yield, %	Lignin content, % of pulp	Pentosan content, % of pulp	Brightness (Hunter), %	Pulp strength properties: Bursting strength, pt./lb./ream at C.S. freeness 500 ml.	Bursting strength, pt./lb./ream at C.S. freeness 300 ml.	Tearing strength, pt./lb./ream at C.S. freeness 500 ml.	Tearing strength, pt./lb./ream at C.S. freeness 300 ml.	Beating time to C.S. freeness 500 ml.	Beating time to C.S. freeness 300 ml.	Classification: Intermediates, %	Classification: Through 150 mesh, %
1	77.4	12.5	21.5	50.8	0.40	0.69	0.94	0.98	65	95	66.7	7.8
2	72.5	11.5	19.8	49.6	0.77	1.02	1.06	0.91	46	70	71.6	0.3
3	67.8	10.9	18.9	43.9	0.85	1.17	1.13	0.96	35	55	63.0	11.7
4	71.4	12.1	19.2	43.3	0.57	0.90	1.22	1.08	33	65	60.8	12.3
5	64.5	10.3	16.0	43.0	0.77	1.16	1.35	1.10	13	34	60.9	13.5
6	59.4	9.5	14.5	43.1	0.57	1.10	1.36	1.18	..	24	61.6	15.9
7	56.4	8.2	13.3	42.0	0.74	1.15	1.30	1.07	..	15	63.2	15.4
8	76.2	13.2	20.4	47.9	0.43	0.75	0.96	0.80	43	80	66.0	8.8
9	68.1	12.2	17.0	45.1	0.62	0.96	1.15	0.98	40	50	63.9	11.3
10	58.1	9.5	13.1	42.7	0.86	1.14	1.17	1.07	6	22	63.5	12.8
11	76.4	11.4	21.1	49.7	0.55	0.81	1.03	0.92	50	70	66.4	7.2
12	73.3	10.4	19.8	50.5	0.50	0.88	1.20	1.00	27	54	63.9	10.6
13	68.2	9.8	19.6	48.8	0.75	1.05	1.15	1.05	13	30	54.2	11.8
14	70.6	10.7	19.6	48.8	0.75	0.98	1.10	1.05	12	16	63.2	13.3
15	63.0	8.7	16.5	47.4	0.79	1.14	1.14	1.50	5	21	64.3	15.8
16	58.5	6.8	14.8	45.2	0.76	1.10	1.14	1.03	..	8	65.8	17.3
17	55.0	4.7	14.3	49.9	0.75	1.17	1.24	0.94	..	12	72.4	16.4
18	75.2	12.1	21.5	52.3	0.41	0.74	1.01	0.93	39	73	63.5	9.4
19	68.7	11.0	17.2	52.6	0.54	0.98	1.18	1.06	4	25	57.9	15.2
20	56.1	6.6	14.0	51.0	...	1.06	...	1.24	..	8	72.3	13.7
21	81.4	13.5	24.0	48.1	0.35	0.56	1.00	1.02	50	80	57.7	19.2
22	78.4	13.2	22.7	45.4	0.50	0.79	1.09	1.02	25	56	58.0	16.8
23	74.2	12.0	21.8	43.8	0.56	0.87	1.13	1.08	40	63	58.5	14.6
24	71.3	12.8	20.0	44.6	0.64	0.99	1.27	1.22	20	43	52.9	17.1
25	68.1	11.8	19.1	42.4	0.66	0.99	1.24	1.10	12	35	58.8	16.0
26	67.2	11.7	19.2	43.1	0.83	1.03	1.28	1.18	20	36	59.4	12.3
27*	65.1	11.5	20.8	46.0	0.93	1.32	1.46	1.15	12	25	62.8	10.6
28	...	14.5	24.0	44.1	0.42	0.62	1.02	1.01	55	70	55.5	12.0
29*	78.7	14.3	23.6	52.7	0.62	0.94	1.12	0.95	25	55	60.8	7.7
30	72.3	13.6	20.2	45.7	0.62	0.94	1.25	1.10	30	48	59.2	12.9
31	68.2	12.5	17.8	42.4	0.59	0.95	1.23	1.24	15	34	59.6	18.2
32*	66.6	12.3	20.2	43.0	0.84	1.30	1.46	1.04	10	30	49.7	31.7
33	77.6	12.1	22.3	47.9	0.42	0.67	0.95	1.07	45	80	62.1	9.8
34*	80.4	12.1	24.9	55.1	0.58	0.87	1.13	0.89	34	60	63.8	6.0
35	75.7	11.5	21.8	48.8	0.57	0.90	1.05	1.01	40	65	64.2	6.5
36*	76.2	11.9	23.8	56.0	0.70	1.03	1.20	1.04	24	44	66.3	7.5
37	74.1	10.8	22.8	47.3	0.64	0.92	1.13	1.03	21	45	60.8	9.5
38*	74.3	11.2	24.5	52.8	0.81	1.20	1.18	1.02	13	30	59.8	9.5
39	69.9	10.3	19.8	47.9	0.70	1.02	1.19	0.98	15	35	61.4	13.4
40	68.4	9.0	19.6	50.8	0.68	1.10	1.28	1.10	7	23	58.3	18.7
41	62.6	7.9	18.6	48.0	0.68	1.01	1.31	1.15	5	20	62.5	17.4
42	78.0	12.6	22.1	49.6	0.43	0.64	1.01	0.98	50	75	59.6	12.8
43	72.4	11.4	20.1	49.3	0.68	0.99	1.22	1.07	27	47	57.6	14.3
44	63.4	9.1	17.4	49.2	0.80	1.15	1.29	1.04	10	25	62.0	17.0
45*	78.8	13.3	25.7	49.8	0.80	1.10	1.06	0.79	8	22	56.5	11.0
46*	74.5	12.2	25.7	50.3	0.84	1.21	1.15	0.95	5	22	53.1	13.8
47*	72.8	10.5	26.0	50.1	0.89	1.13	1.14	0.93	6	17	56.9	6.2
48*	73.3	12.5	24.9	48.6	0.83	1.19	1.19	0.93	11	25	54.7	10.5
49*	71.0	11.3	25.2	49.1	1.03	1.23	1.20	0.95	5	15	49.9	31.0
50*	65.6	8.6	24.2	49.0	1.16	1.40	1.16	0.93	15	25	59.5	3.8
51*	67.8	11.0	22.9	47.6	1.08	1.37	1.14	0.90	10	22	57.7	11.0
52	74.0	17.2	22.4	16.5	0.52	0.83	1.13	1.03	12	37	58.2	14.9
53	74.0	15.1	23.9	21.2	0.65	0.98	1.23	1.05	12	35	48.9	13.8
54	74.2	12.4	24.6	42.3	0.75	1.06	1.18	1.09	15	35	51.0	14.0
55	74.8	12.3	23.0	44.4	0.64	0.90	1.10	0.97	15	37	59.2	14.7
56*	75.0	11.6	25.0	49.5	0.86	1.09	1.20	1.02	10	25	51.9	11.9
57	75.2	11.2	25.8	47.5	0.72	1.08	1.14	0.95	7	27	53.1	12.2
58*	75.5	16.5	23.7	21.2	0.70	0.96	1.13	1.03	11	27	46.1	26.3
59*	75.1	13.1	24.7	43.5	0.85	1.10	1.12	0.98	10	28	52.0	15.7
60*	74.3	12.0	25.1	47.3	0.83	1.07	1.14	0.99	10	20	50.5	16.6
61*	75.4	12.0	25.4	50.6	0.82	1.08	1.09	0.89	6	21	50.1	16.3
62*	75.5	11.7	26.7	50.8	0.79	1.13	1.05	0.90	5	20	55.9	15.2
63	69.5	11.5	23.4	34.5	0.74	1.09	1.30	1.00	15	33	56.4	12.1
64	69.8	10.4	24.4	45.5	0.84	1.17	1.13	0.93	11	27	55.8	12.2
65	68.0	9.9	25.2	50.1	0.85	1.13	1.21	0.90	5	16	45.3	36.8
66	69.1	9.1	26.3	48.0	0.85	1.17	1.14	0.90	3	12	54.9	16.3
67	62.5	8.8	23.9	37.8	1.05	1.29	1.35	1.17	10	26	57.6	13.0
68	59.4	5.9	26.6	47.9	0.98	1.30	1.38	1.06	5	15	65.4	14.5
69	57.2	4.7	26.2	49.5	...	1.23	...	0.95	...	6	70.0	13.8
70*	70.9	13.1	21.6	38.6	0.83	1.11	1.10	0.95	14	29	57.9	11.1
71*	70.5	13.6	23.0	39.5	0.84	1.09	1.17	0.97	16	34	60.1	8.6
72*	68.2	11.9	21.3	46.8	0.87	1.21	1.18	0.93	14	29	63.1	10.1
73*	68.1	11.6	19.4	48.2	0.98	1.29	1.44	1.12	17	32	60.3	9.0
74*	69.1	11.3	21.7	49.8	0.86	1.25	1.32	1.06	14	28	59.9	6.5
75*	69.8	10.9	21.9	52.0	0.93	1.21	1.13	0.91	9	23	63.7	8.8
76*	67.3	10.1	20.7	52.3	0.99	1.33	1.21	1.06	7	19	62.3	12.1
77*	69.1	9.2	22.7	52.2	1.00	1.18	0.98	0.86	3	14	61.3	10.3

[a] The experiments marked with the asterisk were made upon wood B and all others upon wood A.

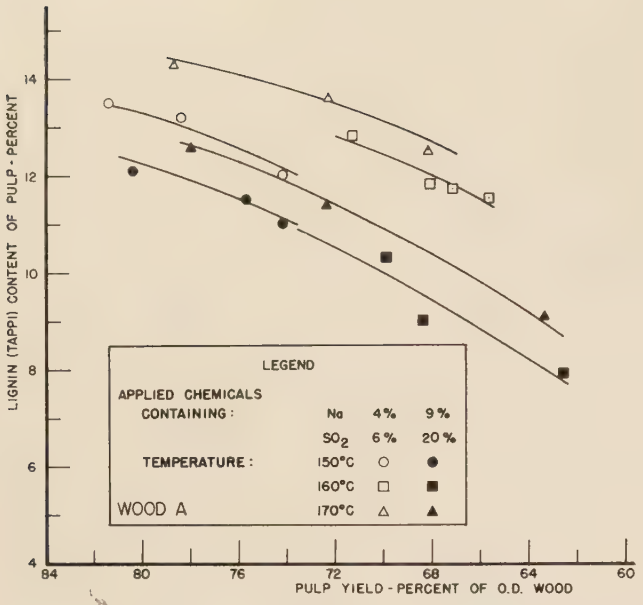

Fig. 13. Lignin contents of various pulps digested at pH 5

the very small proportion of the bisulphite-sulphite buffer system.

The plots of Fig. 11 make it apparent that, as the proportion of sulphur dioxide applied to the wood is increased, its efficiency in the removal of lignin changes abruptly in the range of 4 to 8% of SO_2, on the weight of the wood, when the liquor to wood ratio is 4.7 :1. At either pH 5 or pH 7, lignin removal increases very slightly even with much larger amounts and falls off markedly with lesser amounts. Furthermore, 5% of SO_2 (10% of sodium sulphite) is shown to remove 90%, or more, of the amounts of lignin that can be removed with 10 to 25% of SO_2 at pH 5 or 20 to 50% of sodium sulphite at pH 7.

That the efficiency of the cooking chemicals should vary so may be rationalized with current theory of sulphite pulping if it may be considered that, in digestions with chemicals containing less than 6% (basis: oven-dry wood) of SO_2, lignin removal was limited by inadequate sulphonation. With increasing concentrations of bisulphite ion, sulphonation would proceed more rapidly and extensively. Then, lignin removal in the same period of time (at constant pH and temperature) would increase until the limitation would lie in the rate of hydrolysis and to lesser extent in the limited maximum degree of sulphonation allowed by the environment. Indeed, such limiting conditions have been illustrated by Haggroth, Lindgren, and Saedén (*11*) with data for softwood meal.

Now the correlation made here, that lignin removal is a function of bisulphite ion concentration throughout the range of the bisulphite-sulphite buffer system, is contradicted by Ross, Hart, Strapp, and Yean (*12*). They showed that a sodium sulphite-bisulphite solution of about pH 6 and containing 0.506 moles per liter of SO_2 (equivalent to about 19.5% of SO_2 on the weight of wood used) provided a 93.6% yield of residue from spruce-balsam chips digested for 4 hr. at 140°C. The residue contained 26.6% of TAPPI lignin and 0.85% of sulphur. From a similar experiment employing twice the amounts of sodium hydroxide and sulphur dioxide, they obtained essentially the same yield of residue having 26.1% of lignin and 0.82% of sulphur. They then drew the conclusion that, "the extent of sulphonation was not a function of either the sulphite or bisulphite present." However, their interpretation is in error if it may be agreed that the sulphite ion is ineffective for sulphonation. Their data does not allow for the fact that the proportion of wood acids remained constant and hence the experiment with the greater amount of sodium hydroxide must have taken place at a higher pH level. Of course, the amounts of wood acids provided by spruce and balsam woods are rather smaller than the amounts provided by white birch wood. Nevertheless, they would consume their equivalent of caustic and it is to be observed in Fig. 10 that, above pH 6 (and their two experiments just mentioned would seem to have been made in this range), slight changes in pH effect drastic changes in bisulphite ion concentration and the sulphite-bisulphite ratio. The second experiment then, probably, was not made with twice the concentration of bisulphite and may not have employed a significantly greater concentration. Furthermore, assuming that spruce-balsam wood is affected at pH 6 to 7, by changing bisulphite ion concentration in manner comparable to that shown in Fig. 11 for white birch wood, increasing the amount of applied sulphur dioxide from 19.5 to 39% of the weight of the wood would not be expected to affect the yield of residue significantly and the lignin content but very little, perhaps imperceptibly.

Returning to the plots of Fig. 8, it will be noticed that the curves for any one temperature diverge with time. This divergence should be interpreted by the decreasing efficiency, with time, of the lesser proportion of sulphur dioxide because such solutions approach, with time, much closer to complete consumption of the available bisulphite than do richer solutions.

Lignin Content of Pulps

The result of removing lignin and polyoses from the chips is, of course, softened chips which upon disinte-

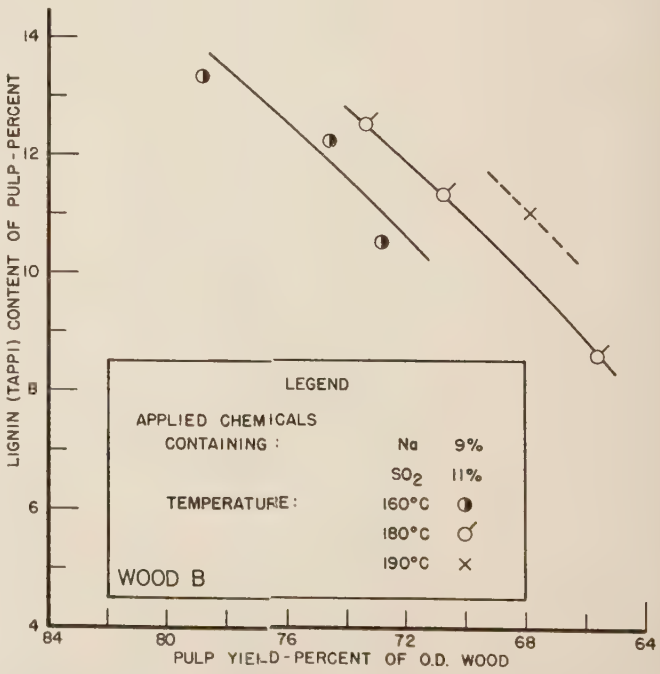

Fig. 14. Lignin contents of various pulps digested at pH 7

gration provide a pulp of some certain lignin content The lignin contents of pulps of diverse yield are shown in Fig. 12 for digestions at pH 4, Fig. 13 for digestions at pH 5, and Fig. 14 for digestions at pH 7.

The first clear observation to be drawn from these plots is that, at each pH level, any fixed proportion of sulphur dioxide provides pulps of higher lignin content as the temperature is increased.

Secondly, with wood A, the effects of pH change upon lignin and carbohydrate removal are such that no less and perhaps a slightly greater proportion of lignin is removed at pH 4 compared to pH 5 (compare the plots of Figs. 12 and 13). Of course, these plots do not allow comparison, at the two pH levels, of digestions with exactly the same proportions of sulphur dioxide, but it has just been shown (Fig. 11) that with more than 8% of SO_2 the rate of gain in lignin removal, with increase of sulphur dioxide, is slight. The digestions with 20% of SO_2 at pH 5 may, then, be compared with digestions made with 23% of SO_2 at pH 4. So comparing, it is found that, at 150°C., digestions to 76% yield at either pH 4 or pH 5 would contain close to 11.5% of lignin.

At pH 5 and 160°C., chemicals containing 6% of SO_2 would provide (Fig. 13) a 70% yield of pulp containing just over 12% of lignin from wood A. This same yield of pulp obtained at pH 4 and 160°C., with chemicals containing 9% of SO_2, would contain 12% of lignin. Digested with only 6% of SO_2, it would contain essentially the same amount as the pulp digested at pH 5.

Unfortunately, the unavoidable change from white birch wood A to white birch wood B during this study

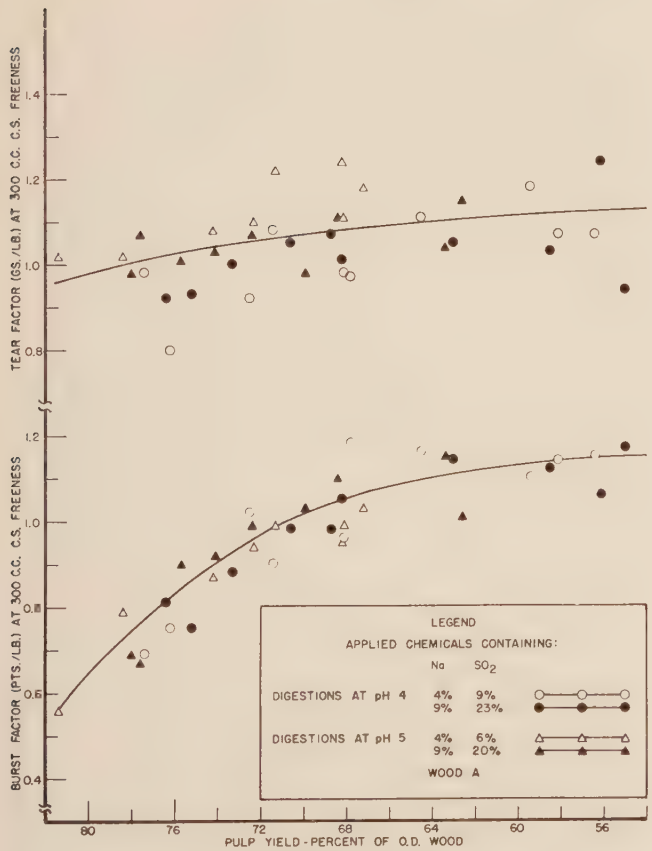

Fig. 15. Burst factor and tear factor versus yield, for pulps from wood A digested at pH 4 and pH 5

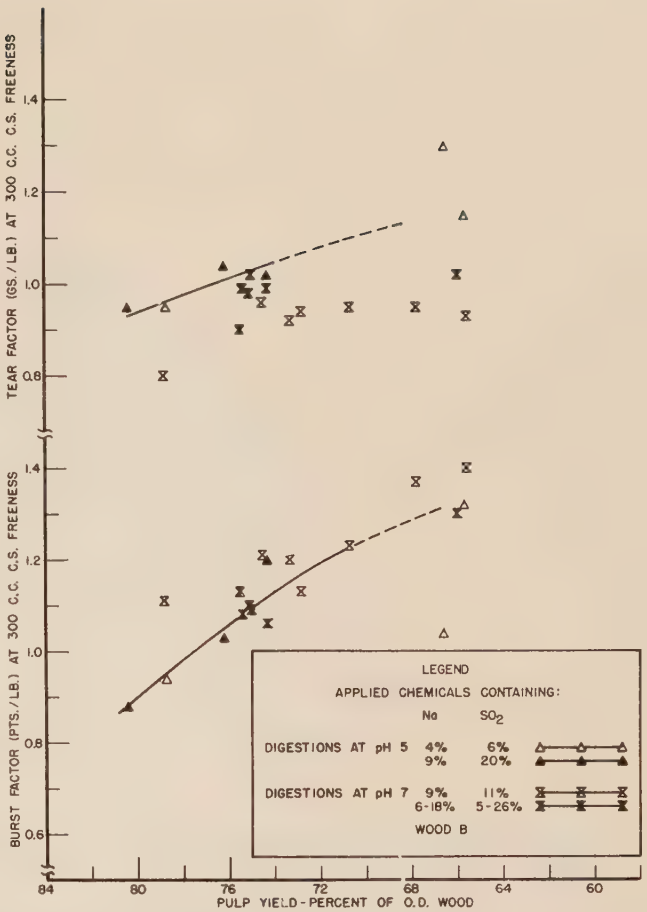

Fig. 16. Burst factor and tear factor versus yield, for pulps from wood B digested at pH 5 and pH 7

prohibits extensive comparison between digestions at pH 4 or pH 5 and those made at pH 7. The few comparisons that can be made indicate that, at pH 7, any chosen quantity of sulphur dioxide is only slightly more, indeed, insignificantly more selective of lignin in digestions of relatively short duration. Thus, at pH 7 and 160°C., 3.25 hr. of digestion with 11% of SO_2 would provide 76% of pulp containing 12.5% of lignin. After 8 to 10 hr. a 70% yield of pulp containing less than 10% of lignin (by extrapolation) could apparently be obtained. At 180°C., 1.25 hr. of digestion would provide a 70% yield of pulp with 11% of lignin. In comparison, at pH 5 and 160°C., the same wood provided 70% of pulp with 11% of lignin after 4 hr. of digestion.

It would seem then that the preparation of semi-chemical pulps with sodium bisulphite at pH levels below 7 has two principal advantages. For any practical proportion of sulphur dioxide the amount of base decreases with pH and for 5% of SO_2 applied at pH 4 is slightly more than one-third that required at pH 7. Secondly, the time required at any temperature or the amount of heat required for any fixed time is less. Whereas, at 160°C. and pH 7 4.5 hr. of digestion produce a 74% yield of pulp containing 11.5 to 12% of lignin, only 1.75 hr. are required at pH 4.

Pulp Strength Properties

The bursting strength and tearing strength, at 300 ml. Canadian Standard freeness, of the pulps prepared at pH 4 and pH 5 are plotted, against the yields of pulps, in Fig. 15. These plots do not reveal any clear

influence of the pH of digestion upon these strength properties. Rather, it would seem that the strength properties relate principally to the yield of pulp and the hydrolytic conditions of digestion. And for any fixed yield these is no suggestion that the slightly different degrees of lignin removal effected by the two different proportions of sulphur dioxide have significant influence upon pulp strength.

Again the change from wood A to wood B prohibits clear comparison of the strengths of pulps digested at pH 7 with those prepared at pH 4 and pH 5. However, Fig. 16 shows the burst and tear strengths for a few pulps prepared at pH 5 and pH 7 from wood B. These plots provide the suggestion that between pH 5 and pH 7 the strength properties are also to be related to the yield and are not otherwise greatly affected by changing conditions of digestion. They also show that the strength properties of pulps prepared from wood B are superior to those shown in Fig. 15 for wood A.

In future communications we will extend some of these relationships and demonstrate further utility of the understanding developed here.

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Laboratory Preparation of Alkali Cellulose According to the Slurry Steeping–Continuous Shredding Process

MILTON O. SCHUR and PETER C. MUFFAT

Laboratory apparatus is described and a procedure given for the preparation of alkali cellulose under reproducible conditions according to the method of slurry steeping and continuous, one-pass shredding. Typical data are presented.

Although the literature mentions laboratory slurry steeping in the preparation of alkali cellulose (*1–4*), no details have been published, so far as the authors know, on equipment or technique. It became necessary to develop a laboratory procedure, in connection with research on the suitability of certain woods for the manufacture of dissolving pulp to be converted into viscose by the process of slurry steeping of drier stock (*5*, *6*, *7*) and one-pass shredding (*8*) of alkali cellulose. Below is a description of the laboratory evaluation procedure, which has been found most helpful in research work.

So far as is practicable and necessary, the laboratory should follow closely the process as used in the plant. In one method of carrying out the process commercially (*8*), fiber, in the form of drier board is fed to a slurry tank, along with steeping liquor returned from the alkali cellulose press and the requisite quantity of fresh steeping liquor. The tank is provided with an agitator which rapidly breaks up the drier sheets and distributes the fiber throughout the slurry. By means of a pump, the stock is circulated from the bottom of the slurry tank to the top through an external pipe, and an amount of pulp equivalent to the feed is directed to a continuous alkali cellulose press. In a typical installation, the calculated average time the fibers are in the tank is about 15 min., on a weight basis. Calculation also indicates that at any moment after equilibrium conditions have been established, 25% (by weight) of the fibers being pumped to the press have been in the tank about 4 minutes or less; 50%, 10 min. or less; 75%, 21 min. or less; 90%, 34 min. or less; 99%, 69 min. or less; and 99.9%, 103 min. or less. Calculation also indicates that when the plant is started up after a shutdown and clean-up, if the tank is first filled with steeping liquor, and then the pulp feed, steeping liquid feed, and discharge pump are started, 99.9% of the equilibrium concentration of fiber is reached in the steeping tank in about 103 min.

In order to approximate this schedule in the laboratory, one might charge a bucket with steeping liquor, and, while maintaining the necessary agitation, add 0.2% of the pulp sample over a 10-min. interval, then 0.2% of the sample over the next 10 min., followed by 0.4, 0.8, 1.56, 3.13, 6.25, 12.5, 25, and 50%, over successive 10-min. intervals, before draining the steeping liquor from the pulp and pressing the pulp cake to the desired press-weight ratio. However, since no two plants would necessarily operate according to the same schedule of rate of feed of pulp, or at the same equilib-

Milton O. Schur, Manager of Research and Development, and Peter C. Muffat, Research Chemist, Ecusta Paper Corp., Pisgah Forest, N. C.

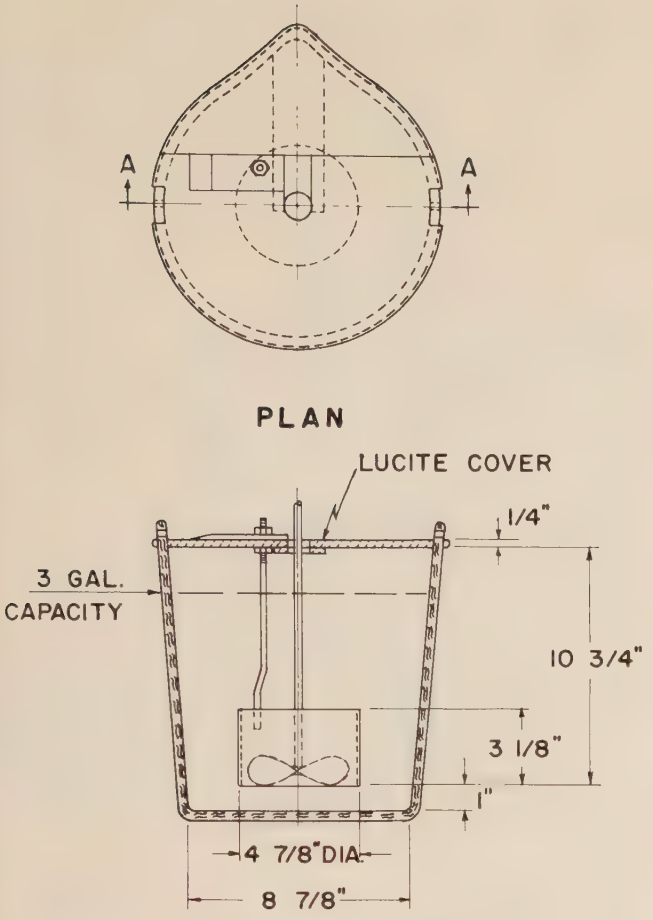

Fig. 1. Slurry bucket

rium concentration of pulp in the slurry tank, or would have the same size slurry tank, etc., and since the time of steeping, in the case of the pulps that occupied the authors' attention, was not found to be important as to effect upon filterability or upon "slowness" of the steeped pulp, within the time limits studied, namely, 5 to 60 min., the pulp was simply added to the slurry bucket over a period of 5 min. and agitation continued for 15 min. before draining the steeping liquor from the pulp.*

Nor was the steeping liquor ordinarily recycled in order to build up the hemicellulose content, for the number of steepings required to attain, say, 95% of the equilibrium concentration of hemicellulose would be at least 45. Such a series of steepings takes about 36 hr. of work, which is best done without a break in schedule if flocculation and settling out of hemicellulose is to be minimized.

A detailed description of the apparatus and procedure used follows:

SLURRY STEEPING

Apparatus

A 3-gal. neoprene bucket is provided with a three-blade stainless steel screw propeller type of agitator, 4 in. in diameter, driven by a 1/4-hp. variable speed motor (Figs. 1 and 2). The bucket is fitted with a removable transparent cover (Lucite) through which the shaft of the agitator passes. Suspended from the cover is a vertical stainless steel rod which supports a stainless steel draft tube. The bottom of the propeller and the bottom of the draft tube are located about 1 in. above the floor of the bucket. The transparent cover is provided with a removable section to facilitate access to the interior of the bucket.

Procedure

Measure 9500 ml. ± 50 ml. of steeping liquor into the neoprene bucket. Start the agitator, using a speed that will produce a gentle vortex above the agitator. Feed 400 grams of pulp, previously conditioned at 60% relative humidity, and cut into sheets 2 by 2 in., into the vortex, piece by piece, as rapidly as possible without clogging the agitator. During the addition, increase the speed of the stirrer as needed to maintain circulation down through the draft tube. Should pieces of pulp become lodged against the stainless steel rod supporting the draft tube, free them with a spatula or the like.

After the charge of pulp has been added, (which should take about 5 min.), continue the stirring for 15 min. at a speed just sufficient to maintain gentle circulation through the draft tube.

PRESSING OF ALKALI CELLULOSE

Apparatus

The slurry press is shown in Figs. 3, 4, 5, and 6. It consists of a vertical cylindrical container, inside diameter 11 3/4 in., lined with stainless steel sheeting. It is provided at the bottom with a perforated Lucite drain plate and with pipe fittings for carrying off steeping

Fig. 2. Slurry bucket

* The fundamental equation upon which these calculations are based is $Wdc = cdw$, where W = total weight of slurry in steeping tank after equilibrium conditions are attained, c = concentration of pulp (weight fraction) in slurry under those conditions; and w = weight of slurry being removed per second. From the fundamental equation, it follows that the fraction of all fibers in tank which have been there t min. or less = $\int_0^t e^{-kt}dt / \int_0^\alpha e^{-kt}dt$, where $k = w/W$.

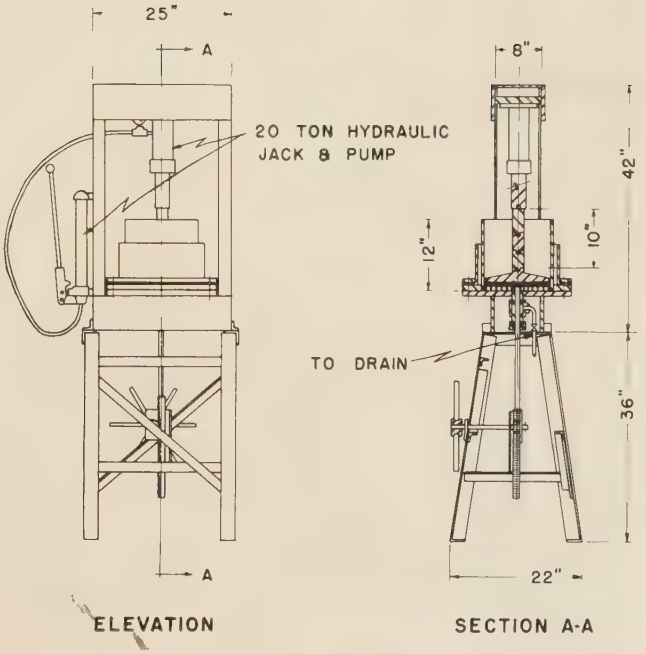

Fig. 3. Press

liquor. The bottom of the drain plate is grooved so as to permit free flow of liquor from any perforation to the drain pipe.

Resting on the drain plate is a 16-mesh wire screen on top of which are a perforated metal plate and two layers of 16-mesh wire screen. The perforated metal plate is fastened by means of a machine screw to the top end of a vertical rod which passes through a packing gland at the bottom of the press. The rod, and therefore the perforated metal plate, may be raised or lowered by means of a rack and pinion, as shown in the figure.

The steeping press is also provided with a removable platen, $11^1/_2$ in. in diameter, and a hydraulic ram by means of which the platen can be forced downward in the container.

All metal parts coming in contact with the steeping liquor are of stainless steel.

Procedure

Lower the perforated metal plate as far as it will go, place two of the 16-mesh stainless steel screens on the perforated metal plate, and shut the drain valve. Pour

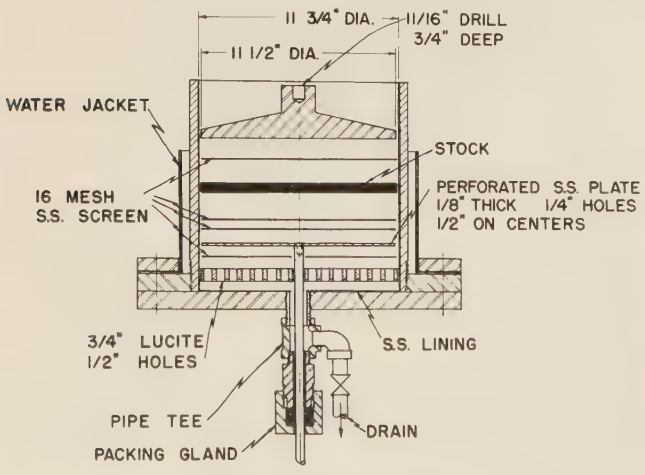

Fig. 4. Press detail

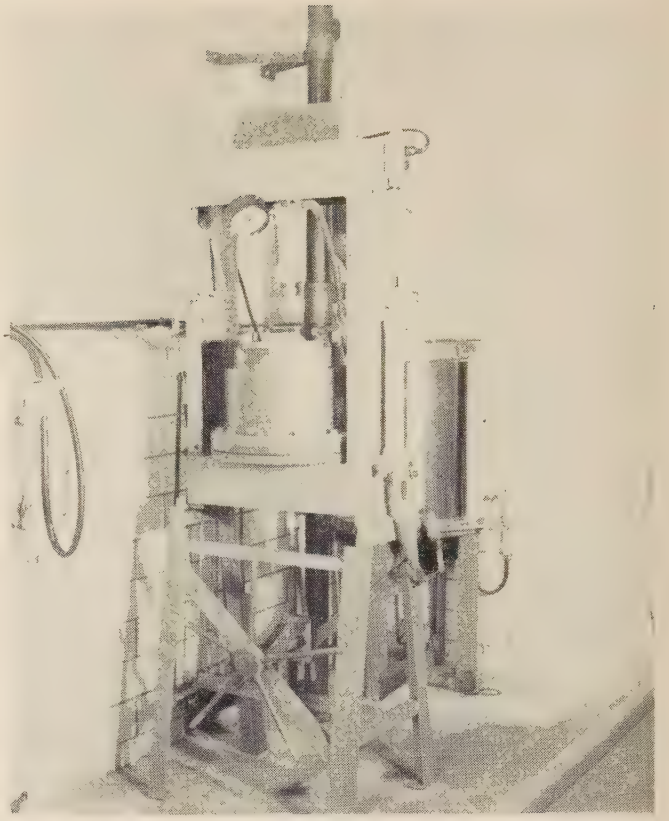

Fig. 5. Press

the pulp slurry into the container. Open the drain valve, and note the rate at which the steeping liquor drains from the pulp (as by recording the number of seconds for 2 liters and for 3 liters of liquor to come through). Now place a 16-mesh wire screen on the surface of the drained pulp, place the removable platen on the uppermost wire screen, and apply hydraulic pressure to the platen until the desired press weight ratio is almost attained, as estimated from the total volume of steeping liquor drained and expressed from the pulp.

Remove the platen from the container, raise the press cake by means of the rack and pinion arrangement and weigh the cake. From the weight, calculate the number of milliliters of steeping liquor yet to be expressed from the cake.

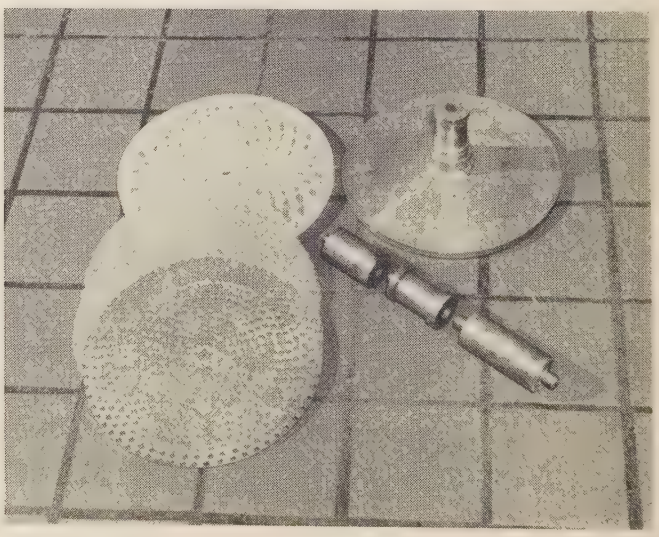

Fig. 6. Press parts

Table I. Typical Data for Various Pulps

	Western softwoods	*New England hardwoods*	*Sweet gum*	*Shortleaf pine*
Type of cook	Sulphite	Sulphite	Prehydrolyzed kraft	Prehydrolyzed kraft
Average fiber length, mm.	1.4	0.6	1.0	2.5
Alpha-cellulose content, %	90.5	86.1	93.0	95.0
Time to drain 3 liters steeping liquor, sec.	82	150	68	73
Press-weight ratio after 5 min. at 20,000 lb. pressure	3.00	2.75	2.70	2.95
Filterability	655	500	420	175

Replace the press cake in the container, the 16-mesh screen and the platen. Apply hydraulic pressure until the calculated final number of milliliters of steeping liquor have drained from the press. Remove the press cake and reweigh. The weight should be very close to that desired.

Notes:

1. For the closest work, it is recommended that the container be jacketed in order that the temperature of the steeping liquor can be maintained constant during the draining and pressing steps.
2. During the pressing of the cake, a relatively small quantity of steeping liquor will rise around the platen. This layer of liquor is readily sucked out of the steeping container through a rubber tube attached to a suction flask. Its volume is taken into consideration in estimating when the desired press ratio has been approached during the pressing operation.
3. The behavior of the alkali cellulose to be expected in plant pressing operations is manifestly indicated by (1) the time required for the free draining of steeping liquor, (2) the maximum pressure required to give the desired press ratio, (3) the rate of draining of liquor from the cake while some standard pressure is applied to it, and (4) the press ratio obtained in (3).
4. The thickness of the press cake will ordinarily be found to be between 1.7 and 2.2 cm., depending on the pulp.

ONE-PASS SHREDDING

Apparatus

A Sprout-Waldron shredder, type 12, with plates 17779-S and 17780-R, is used. A sheet metal adapter is provided at the outlet of the shredder to facilitate air-tight attachment of a polyethylene bag which receives the shredded alkali cellulose without permitting flow of air through the shredder (Figs. 7 and 8).

Procedure

To adjust the clearance between the plates of the shredder, turn the adjusting handwheel until the plates touch, then turn the handwheel in the opposite direction three full turns. Each complete turn changes the clearance between the plates 2.0 mm. Tighten the lock nut and start the shredder.

Tear the press cake apart by hand into pieces about 1 in. across and feed the pieces into the shredder hopper as fast as the shredder will take the stock. The time each piece is in the shredder is only a second or two. The entire time consumed in feeding the press cake into the hopper is only about 2 or 3 min.

Note: Too narrow a clearance between the shredder plates may cause low filterability results. The clearance used should be about the largest that will give shreds free from chunks of press cake.

PREPARATION OF VISCOSE SOLUTION

Compress the alkali cellulose to a bulk density of 200 to 250 grams per liter (*8*). This can be done in any convenient way, as by means of a plunger in a cylindrical container. Age the alkali cellulose, xanthate it, prepare viscose solutions according to any desired schedule, and measure filterability.

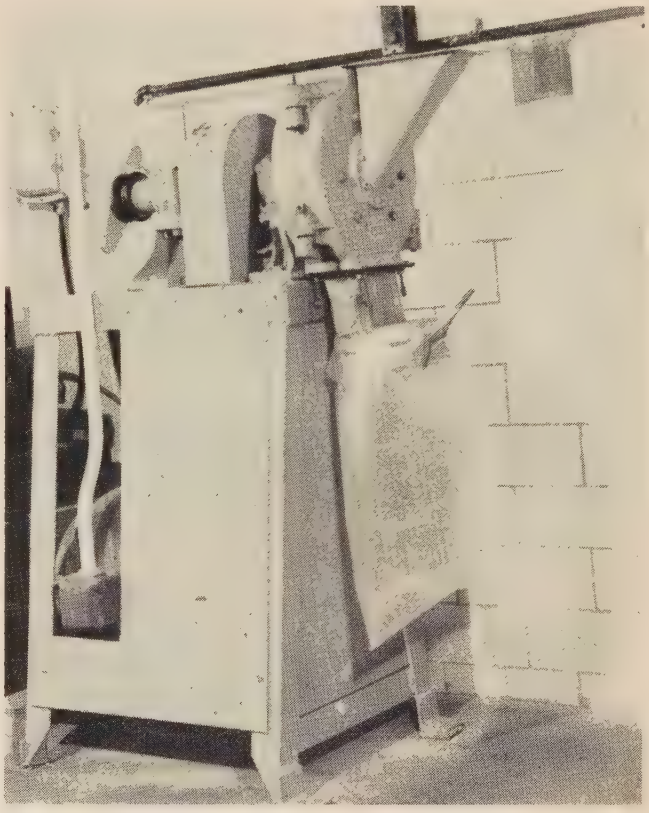

Fig. 7. Sprout Waldron shredder

TYPICAL EXPERIMENTAL DATA

By way of example, data obtained with a number of different pulps are given in Table I. Filterability is expressed as grams of viscose passing through 1 sq. in. of filtering medium up to the time the filter plugs.

The details of the conditions used in the preparation of the viscose are as follows:

1. Steeping: Liquor concentration, 17.5% NaOH, initial temperature, 36°C.
2. Press-weight ratio: 2.70 ± 0.05 (weight of press cake divided by the weight of pulp added to the steeping bucket).
3. Aging: At 30 to 35°C. until the cupriethylenediamine viscosity of the cellulose in the press cake drops to 2.7 to 3.0 cp. by TAPPI Standard T-230 (0.5% cellulose in cupriethylenediamine). The sample of cellulose taken from the cake for the viscosity test is freed of caustic soda by acidification of the alkali cellulose with acetic acid, then is washed and dried.
4. Carbon disulphide charge: 28%, based on cellulose in the alkali cellulose. Cellulose is determined by

Table II. Filterability of Pulps Before and After Being Precut in Wiley Mill

Description of pulp used	Process used in mfr. of pulp	Filterability: 2 by 2-in. sheets	Filterability: Wiley mill material	Fiber length, mm.: 2 by 2-in. sheets	Fiber length, mm.: Wiley mill material
Western softwoods	Sulphite	600	630	1.2	...
Southern pine pulp	Sulphite	220	790	1.8	...
Scotch pine pulp	Prehydrolyzed kraft	250	460	1.6	0.7
Laboratory pulp prepared from shortleaf pine	Prehydrolyzed kraft	175	525	2.5	0.8
Laboratory pulp prepared from loblolly pine	Prehydrolyzed kraft	125	510	2.4	0.7

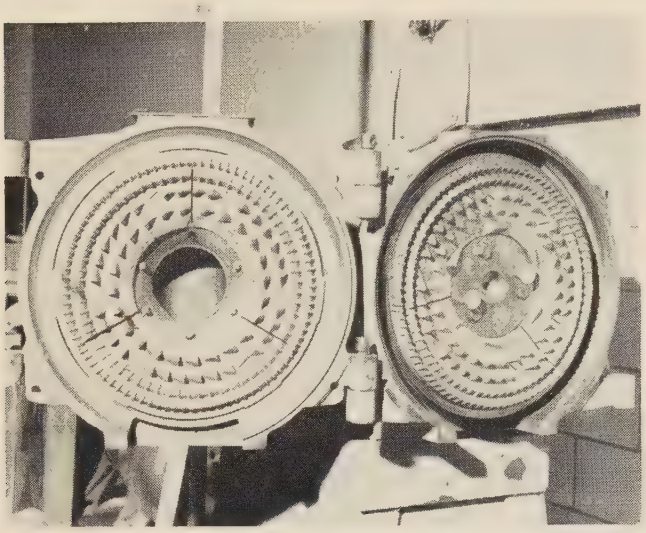

Fig. 8. Sprout Waldron shredder, open

acidification of the alkali cellulose with acetic acid, followed by washing and drying of the residue.

5. Time and temperature of xanthation: 120 min. at 30°C.
6. Dissolving: 150 min. at 18°C.
7. Composition of viscose: 8.5% cellulose (material insoluble in dilute sulphuric acid) and 5.25% NaOH by weight.
8. Ripening time: 0 hr.
9. Pressure in filter: 60 p.s.i.
10. Area of filter: 1.603 sq. cm.
11. Filter medium: The viscose passes first through a layer of unbleached sheeting, thread count 48 by 44, 3.9 oz. per sq. yd., then through a layer of cotton batting, 4.0 oz. per sq. yd., and finally through a layer of canton flannel, thread count 40 by 65, 6 oz. per sq. yd., nap side in.

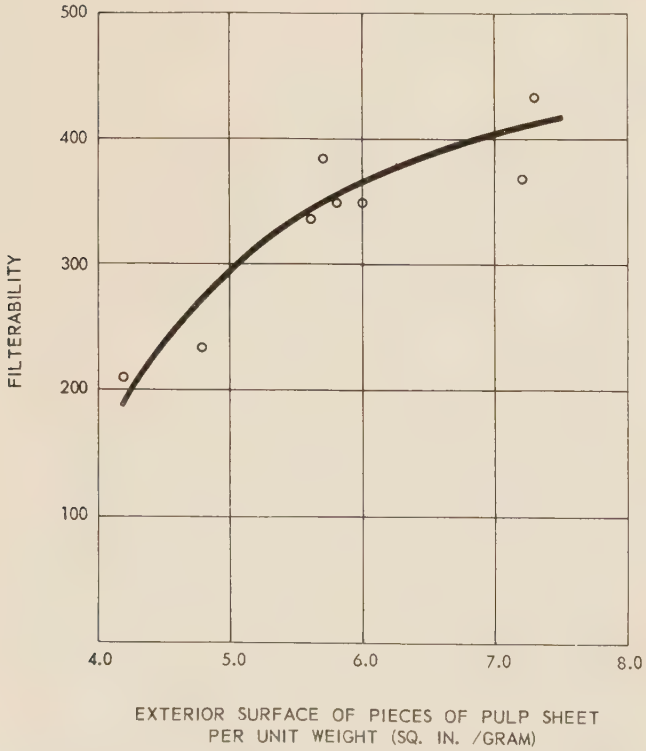

Fig. 9. Effect of cutting of pulp sheets on filterability

STUDY OF THE EFFECT OF SIZE OF PULP SHEETS

On the basis of a working hypothesis evolved during research on the pulping of southern pines, the authors were led to study the effect on filterability of increasing the area of the pulp sheet available for absorption of the steeping liquor. It was found that if the size of the pieces of pulp sheet, cut with shears to predetermined dimensions, is greatly reduced, the filterability of pine pulps is markedly improved.

The experimental data obtained are shown in Fig. 9. The conditions of temperature, time, concentration, etc. used in the preparation of the viscose were as given in the preceding section.

In another experiment, drier stock was cut in a Wiley mill provided with a coarse screen. Of the cut material, 95% was retained on a screen having openings 1.0 by 1.0 mm., 50% on a screen having openings 2.0 by 2.0 mm. The results obtained are given in Table II.

The data given in Tables I and II and in Fig. 9 are indicative of the kind of information that may be secured with the apparatus and procedure described above. The conditions used in the preparation of the viscose solution are, of course, subject to considerable variation. Those outlined are manifestly unfavorable for the attainment of highest filterability; on the other hand, they tend to distinguish more readily between pulps.

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Preliminary Investigations on Alkaline Pulping of Bamboo

REAVIS C. SPROULL

Preliminary data are given on the alkaline pulping of several varieties of bamboo with cooking conditions, yields, and handsheet properties cited.

THE paper industry is a very dynamic one. In 14 years it has more than doubled its consumption of raw material and the per capita consumption of paper products has more than doubled (*1*). Reliable predictions adjudge this to be a sustained growth condition. For this reason more and more raw material will be needed. A potential source is bamboo whose new culms, once a clump is established, make their full growth within a 6-week period in each year (*2*). This plant can also be grown in large quantities on land in the south which is presently nonproductive.

Many species of bamboos have been used for the manufacture of limited quantities of paper in many foreign countries. The report from the Engineering Experiment Station of the Georgia Institute of Technology (pp. 24, 26) comprehensively surveys the use of bamboo in those countries. Most of the methods used would not be practical for mass production in the United States.

Bamboo paper has attained the rating of a major industry only in India and Pakistan where about 80,000 tons per year of bamboo pulp are being used in a variety of papers.

Most of the known methods of pulping have been applied to bamboo. Least promising of the conventional methods is mechanical pulping. This may be attributed to difficulty of holding the culm against the stone, the difference in structure of the node and internode, and change in hardness with drying.

The sulphite, semichemical, and other acid or neutral methods have not shown as much promise as alkaline processes. Good pulps have been obtained by the soda and kraft processes or modifications thereof.

Two modifications, the Gruco process (*3*) and the Raitt process (*4*), have yielded the best quality pulps. These both may be considered as mild modified kraft or modified soda cooks.

The Gruco method consists of: (a) a cooking liquor composed of 75 to 80 grams of NaOH plus 12 to 15 grams of Na_2S per liter of liquor, (b) a total cooking period not in excess of 4 hr., (c) reduction of the cooking temperature to range of 140 to 160°C.

In the Raitt process the principle of "fractional digestion" is applied (*4–7*). The process consists of removal of soluble substances in the raw material by stages according to their different degrees of solubility, using a combination of spent liquor and caustic. The reason for this is discussed in references (*2*) and (*8*) and is based on selective removal of the three undesirable components, namely: (1) water-soluble salts, starches, sugars, etc.; (2) soluble pectins, fats, waxes, and gums in 1% alkali at 100°C.; and (3) alkali-soluble lignin, acids, etc., in 4% alkali at 130°C. Removal is accomplished in two stages.

Table I shows results obtained at Herty on two pilot plant kraft cooks using *Phyllostachys bambusoides* (*9*).

In another kraft series directed at making pulp for unbleached papers a yield of 40% was obtained using 15% active Na_2O at a cooking time of 2 hr., a pressure of 100 p.s.i., and a cooking temperature of 165 to 169°C. The permanganate numbers were in the range of 16 to 27 (*9*). Boards of various weights were made from this pulp and from mixtures with other pulps.

The bamboo kraft pulp appears to be intermediate in properties between pulp of southern pine and southern gum. The chips pulped to a permanganate number of 17 with consumption of 14% active alkali as Na_2O. The use of 18% Na_2O gave a pulp of 10.4 permanganate number.

CURRENT EXPERIMENTS

The length and width of the raw bamboo fiber and samples of pulp made therefrom have been measured. These data will be reported elsewhere. Two points of interest may be the method of preparing the raw fiber by soaking in 10% NaOH for 18 min. at 15 p.s.i. and the use of a Projektina as a rapid screening device for fiber dimensions.

Generally the fiber lengths of the bamboos are about like hardwood but the bamboos show a higher length to width ratio. Table II shows a comparison of some species. Other determinations have been made. The results are of the same order of magnitude.

Kraft and modified Raitt processes have been applied with southern pine as reference.

Exploratory cooks were made with water and dilute alkali at 140 to 160°C. to obtain a semiquantitative measure of the product quality, yield, and alkali required to neutralize the bamboo acids and maintain a safe pH. To maintain a pH of 8 to 9 about 8% NaOH on the basis of the dry bamboo was required at an unbleached unrefined pulp yield of 85%. The soda cooked semichemical pulp was of poor quality.

Kraft Cooks. After varying ratio and conditions the general conditions of 18% active Na_2O and 19% sulphidity at a liquor to fiber ratio of 8:1 for 2 hr. at 160 to 170°C. were adopted. Cooking was done in a small stationary, gas-fired digester with liquor circulated. Fifteen hundred to eighteen hundred grams, calculated dry, bamboo was used for each cook.

Cooks were made from different positions along the culm, some near the base, the middle, and top. The wet pulp was hammermilled, wet yield determined, and the pulp air dried.

The weight contained in a cubic foot box was used to determine apparent density of some of the chips. Bleachability potential was measured by the modified

REAVIS C. SPROULL, Director, Herty Foundation, Savannah, Ga.

Table I. Pilot Plant Kraft Cooks (9)

Conditions and results	Cook no. 1	Cook no. 2
Total alkali, g./l. Na_2O	96.5	93.6
Active alkali, g./l. Na_2O	86.9	84.2
Per cent Na_2O on chips	18.0	14.0
Ratio of wood to total liquor	1:4.0	1:4.0
Ratio of wood to black liquor	1:0.7	1:0.7
Maximum cooking temperature, °C.	176	176
Time to maximum temperature, hr.	1.0	1.0
Total cooking time, hr.	3.5	3.5
Per cent screened pulp yield	36.2	38.2
Per cent screenings, based on chips	0.0	0.4
TAPPI permanganate number	10.4	16.9
Chlorine consumption, %	5.25	7.77
Bleached brightness, G.E.	75	81.9
Bursting strength unbleached, factor range	1.61–1.86	
Bursting strength bleached, factor range	1.28–1.60	
Tear unbleached, factor range	5.15–3.82	
Tear bleached, factor range	3.26–2.70	

Tingle number (*11*) and fiber classifications were made on the Clark classifier. Typical results are shown in Table III. On thorough drying the pulp was difficult to re-wet. The use of a small Dynapulper assisted the wetting without hydrating the pulp.

Comparing yields, based on 59 cooks, some not listed in the table, the bottom gave a composite yield of 52%, whereas the middle and top sections gave a yield of 50%. This would not be significant to justify separation, especially when the difference in volume between the sections is considered.

Within the limitations of these data, the pine and bamboo yields and chlorine consumption are much alike. The bamboo shows a higher percentage of fine fibers, as would be expected from the fiber dimensions.

Raitt Process. A preliminary series of two step cooks using about 170 grams, calculated, dry bamboo were carried out in small digesters in which four cooks could be made at a time. This was done to establish the broad limits of the process and examine the quality of the product. This led to a consideration of the Raitt process as reported by Parekh (*4*).

This is as follows:

1. Crushed bamboo is extracted for about 2 hr. with a partially exhausted alkaline solution containing about 2% of active alkali from a previous cook at a temperature of 100 to 115°C.

Table II. Dimensions of Papermaking Fibers

	Fiber length, mm.	Length to width ratio[a]
Wood Species (*10, 2*)[a]		
White spruce	3.5	120
Douglas-fir	5.0	100
Southern pine	4–6	110
White pine	3.5	100
Cypress	6.0	105
Redwood	7.0	105
Western hemlock	4.0	120
Aspen	1.3	56
Yellow birch	1.5	66
Black gum	1.7	70
Yellow poplar	1.8	60
Red gum	1.6	57
Maple	1.0	30 (red)
Bamboo (Herty)[b]		
P. sulphurea viridis	1.9–1.1	154–123
P. vivax	1.6–1.0	142–114
P. bambusoides	1.6–0.9	173–104
P. nigra var. *henonis*	1.6–1.3	143–188
P. dulcis	1.4	127–169
Bambusa vulgaris	2.2–2.5	225–255

[a] By private communication from Institute of Paper Chemistry, Appleton, Wis.
[b] Herty data.

Table III. Yields (Unscreened) Kraft Cooks—Varying Species and Position in Culm

Cook no.	Position in culm[a]	Species	Weight, cu. ft.	Yield, %	Fiber classification, % on 14	28	50	100	Through 100	Modified Tingle (11) no.
7	B	*bambusoides*	15.1	61	Difficulty re-wetting					
8	M	*bambusoides*	11.2	49	Difficulty re-wetting					
9	T	*bambusoides*	9.2	52	Difficulty re-wetting					
10	W	*aurea*	10.1	48	Difficulty re-wetting	...	...	...		14.5
11	B	*aurea*	13.2	51	Difficulty re-wetting	...	...	...		14.0
12	M	*aurea*	11.7	50	Difficulty re-wetting	...	...	...		14.6
13	T	*aurea*	10.3	52	5.3	32.3	33.2	11.5	26.8	14.8
14	W	Pine	13.8	49	48.5	15.2	5.6	1.2	29.2	13.4
19	B	*vivax*	14.5	58	35.4	29.8	9.8	9.2	15.9	15.0
20	M	*vivax*	...	54	35.6	28.1	9.8	9.0	16.8	14.2
21	T	*vivax*	...	43	16.2	16.6	8.9	11.0	49.5	12.8
22	B	*Purpurata*	...	49	13.5	19.4	17.7	5.7	43.7	14.0
23	T	*Purpurata*	...	52	22.8	23.0	21.0	9.2	24.0	13.5
24	B	*Purpurata*	...	54	31.1	23.2	16.7	5.8	22.9	12.1
25	M	*Purpurata*	...	46	18.9	19.5	17.6	6.1	37.9	13.8
26	T	*Purpurata*	...	50	19.0	25.9	22.0	8.6	24.7	13.1
27	B	*Rubromarganata*	...	54	41.6	20.3	18.0	3.2	18.9	14.1
28	M	*Rubromarganata*	...	54	45.4	21.1	15.9	5.1	12.4	14.0
29	T	*Rubromarganata*	...	48	28.1	28.7	7.1	5.5	30.7	14.0
31	B	*Nedularia*	...	52	24.8	27.4	21.6	8.2	18.0	15.1
32		*Nedularia*	...	42	27.6	24.4	16.8	7.1	24.2	15.8
33	T	*Nedularia*	...	53	17.9	23.1	22.0	17.9	19.0	15.5
34	B	*B. tuldoides*	...	53	31.5	27.3	18.6	5.7	16.7	16.0
35	T	*B. tuldoides*	...	55	34.0	23.3	17.3	6.0	9.4	16.2
36	B	*B. longespeculata*	...	57	43.0	20.7	18.3	5.8	12.3	16.0
37	T	*B. longespeculata*	...	58	43.8	21.6	14.4	4.6	15.7	13.6
40	B	*vulgaris*	...	54	43.3	18.8	12.4	5.8	19.7	14.1
41	T	*vulgaris*	...	53	40.8	24.2	12.4	7.6	14.9	14.0
44	B	*meyeri*	...	60	17.1	37.9	9.4	13.0	22.6	11.1
45	M	*meyeri*	...	50	20.3	38.3	8.8	12.2	20.4	15.0
46	T	*meyeri*	...	53	14.3	37.8	10.5	14.3	23.1	13.7

[a] B = bottom. M = middle. T = top. W = whole.

Table IV. Digester Yield (Lb. per Cu. Ft.)

Cook no.	Lb. per cu. ft. as charged	Moisture, %	Lb. per cu. ft. moisture-free	Yield, %	Yield, lb. per cu. ft. moisture-free	Yield, lb. per cu. ft. air-dry
60	17	18.2	13.9	52.6	7.3	8.2
61	11 1/4	10.3	10.1	43.6	4.4	4.9
62	14 1/4	11.6	12.6	44.4	5.6	6.2
63	15	10.7	13.4	41.0	5.5	6.1
64	16 1/2	13.3	14.3	48.5	6.9	7.7
65	12 1/2	13.6	10.8	45.9	5.0	5.5
66	16 1/4	13.3	14.1	44.0	6.2	6.9
67	15	12.0	13.2	44.9	5.9	6.6
68	13	10.0	11.7	41.3	4.8	5.4

	Pulp fiber classification results, % — Cook no.								
	60	61	62	63	64	65	66	67	68
On 14 mesh	14.5	22.1	12.1	7.7	8.5	9.2	0.41	19.9	11.8
On 28 mesh	42.8	31.0	45.6	46.5	33.9	27.6	30.2	42.2	21.3
On 50 mesh	19.2	14.6	18.9	23.7	17.0	15.8	17.4	13.0	14.9
On 100 mesh	9.5	8.0	10.4	7.2	11.5	8.0	12.9	10.4	9.7
Total recovered (*9*)	85.9	75.7	87.0	84.6	70.9	60.5	60.8	85.5	57.7
Through 100 mesh	14.1	24.3	13.1	15.5	29.1	39.5	39.2	14.5	42.3

2. The predigested material is then cooked in a fresh caustic solution (containing about 5%) for 3 hr., one at 150°C., and the remaining two at 140°C. Best results are obtained by the sulphate process, re-using the waste liquor.

Thirty small cooks were made in the range of conditions described by Parekh with pine as reference. The bamboo pulp yields were in the range of 38 to 51% and the pulps were of good quality, whereas the pine yielded 73% but was not suitable for papermaking.

Another series of nine cooks was made using the 5-lb. digester with conditions as follows:

1. Enough black liquor containing 20 grams per liter active alkali, calculated as NaOH, to cover the material was held at 100° to 110°C. for 2 hr. Then the liquor was drained.
2. The extracted charge was covered with white liquor containing 50 grams per liter of active alkali calculated as NaOH. This was held at about 150°C. for 1 hr., then at 130 to 140°C. for 2 hr.

The alkali from the first stage was exhausted, whereas the black liquor from the second stage contained very close to 20 grams per liter active alkali as NaOH.

The pulp from this series was readily disintegrated without the use of the hammermill. Table IV shows the digester yields and Clark fiber classification (*12*). The significance of "digester yield" in mill operation rests upon the high cost of the digester. The more pulp obtained per cook the lower the capital cost of cooking. It is worth noting that the yields from bamboo in these experimental cooks fall in line with good pulp mill operation on southern woods.

The nine pulps were evaluated by beating in the 1 1/2-lb. Valley beater, making handsheets at suitable intervals and testing the sheets. The procedures were

Table V. Results of Beater Evaluations

Cook no.	Time, min.	Burst factor	Tear factor	Freeness ml.	Description of material cooked
			Section A. Comparisons at 400 ml. C. S. Freeness:		
60	59	0.65	2.07		*P. bambusoides* 40842, whole culm no. 10
61	48	0.72	2.46		*P. purpurata* 77006, whole culm, no. 10
62	60	0.43	2.19		*G. angustifolia* 132895, bottom section
63	45	0.70	2.50		*B. vulgaris* (no number whole culm)
64	47	0.51	1.80		*P. sulphurea virides* 77257, whole culm
65	41	0.40	1.51		*P. nigra*, culm no. 824761, whole culm
66	40	0.47	1.39		*P. bambusoides* 80064 nos. 5 and 6, composite, whole culm
67	53	0.52	1.68		*B. tuldoides* 21349 or 80875 (?), whole culm
68	62	0.15	2.15		*B. longispiculata* 178809
			Section B. Comparisons at Maximum Burst		
60	75	0.68	1.51	219	
61	50	0.78	2.49	306	
62	80	0.67	2.28	271	
63	65	0.90	2.37	238	
64	55	0.56	1.56	209	
65	65	0.66	1.33	222	
66	65	0.65	1.41	157	
67	75	0.69	1.98	200	
68	70	1.14	2.12	371	
			Section C. Comparisons at Maximum Tear		
60	45	0.54	2.91	463	
61	50	0.78	2.49	306	
65	65	0.47	2.30	348	
63	50	0.76	2.52	349	
64	45	0.50	1.83	423	
65	45	0.45	1.58	371	
66	50	0.47	1.42	300	
67	75	0.69	1.98	200	
68	50	0.46	2.15	514	

similar to corresponding TAPPI Standards but not identical. Samples were conditioned before test. Summarized results are shown in Table V.

Again it may be concluded that the bamboo pulp is readily refined to a condition from which a sheet intermediate in strength between softwood and hardwood krafts can be made.

Subsequent to the information reported herein, pilot machine runs have been made applying the Raitt principle successfully. This report must be considered preliminary as many important details are omitted and approval for publication must be obtained from our sponsor.

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A Rapid Method of Estimating the Titanium Dioxide Pigment in Paper

HAROLD C. BRILL

Certain beater additives have a marked effect on titanium dioxide retention and this property may vary widely in mills returning coated paper broke to the beater. This indicates the need for regular and systematic analyses of the paper production for titanium dioxide content to prevent loss. The present titanium dioxide analyses methods are time consuming and require personnel with skill in analytical chemistry. A method is needed that is rapid and simple and can be performed by the regular mill employee in 15 min. or less. The method need not be as accurate as present analyses and might be considered an estimation. A simple method of estimating the titanium dioxide pigment content of a paper from the opacity of a waxed or oiled sheet is discussed in this paper. This test is designed to supplement the existing analytical methods and is not intended as a replacement.

Based on conversations with various mill men at numerous paper manufacturing concerns throughout the country, it was learned that very few plants run titanium dioxide analyses on their production at regular intervals. Many mills could reduce the costs of titanium dioxide usage through improved control. A previous paper (*3*) has shown that various additives markedly affect the beater retention of titanium dioxide. The increased use of such additives and their presence in waste paper make it desirable to determine titanium dioxide concentration or retention frequently. This is particularly true in printing papers where the air interface opacity is affected by many conditions other than titanium dioxide content.

It is believed that the major reason for the reluctance of these mills to make tests is due to time-consuming methods now used in determining titanium dioxide and the need for personnel with some skill in analytical chemistry. The papermaker has a definite need for a rapid method of analysis to insure the production of paper with the desired titanium dioxide content and thereby reduce pigment wastage. Such a method need not be as accurate as the standard methods but should be sufficiently rapid and simple that it can be performed by the mill employee in fifteen minutes or less.

The method proposed in this paper is based on the fact that only high refractive index pigments such as titanium dioxide, zinc sulphide, zinc oxide, antimony oxide, etc., will give pigmented papers any appreciable waxed or oiled opacity (*1*). Paper fiber, clay, calcium carbonate, and other common paper chemicals have a refractive index of approximately 1.5 and depend upon the presence of an air interface (refractive index = 1) for their opacity. These fillers lose their opacity when the air interface is replaced with an oil or wax with the same refractive index.

This paper deals with the estimation of anatase titanium dioxide alone in paper although similar methods could be developed for use with rutile titanium dioxide and other high refractive index pigments. The procedure is proposed to supplement existing analytical titanium dioxide methods and not to replace them.

The data shown in this paper are confined to beater added titanium dioxide. Pigment added in coatings is readily estimated from weighing the paper before and after coating and for this reason is not discussed.

PROCEDURE

Those concerns, where regular titanium dioxide analyses are made on their papers, can prepare graphs of the correct range by selecting the proper retained samples,

Harold C. Brill, Technical Service Laboratory, E. I. du Pont de Nemours & Co., Pigments Dept., Newport, Del.

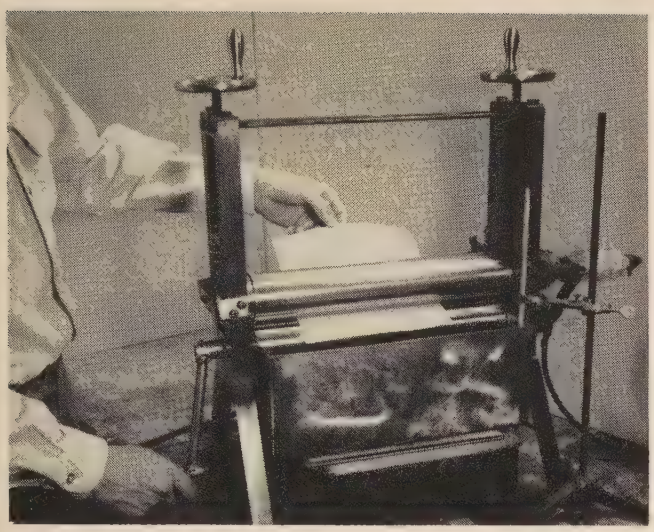

Fig. 1

waxing, and determining opacity. The author would suggest that other mills prepare their graphs by laboratory handsheet technique using the same furnishes run in the mill. The preparation of satisfactory handsheets for this purpose should be done by TAPPI Standard T 218 m and they should be analyzed for titanium dioxide using either the volumetric method T 439 m-44 or the colorimetric method T 627 m-45. If other fillers are not present, the titanium dioxide may be determined by ashing and weighing.

Mills that do not wish to take the trouble of preparing graphs for all their titanium dioxide containing grades of paper may follow their pigment retention by determining the waxed opacity of a satisfactory sheet of paper which meets their customers' specifications. This paper should be set up as a standard and future production must have the same waxed opacity as a measure of equal titanium dioxide content. This value may be approximately correlated to titanium dioxide content using Fig. 4.

Wax or Oil Impregnation of the Paper

Apparatus. The type of apparatus for impregnating the paper may be very simple. It is suggested that the impregnant be heated to a constant temperature and, for this reason, it is believed that the wax or oil should be heated in a boiling water bath or other means of controlled heating used. A means of removing the excess impregnant must be provided and this may take the form of a pair of heated squeeze rolls or a pair of knives with adjustable clearance. A photograph of an apparatus for impregnation is shown in Fig. 1, although a much less elaborate setup may be adequate.

Impregnant. The two impregnants used in this study were paraffin wax and medicinal grade of mineral oil. Paraffin wax is an excellent impregnant with a low melting point; it is cheap, readily available, and paper is readily impregnated with it. However, it does have some opacity and care must be exercised to avoid a large excess, or an error in the waxed opacity reading may result at low titanium dioxide content (see Fig. 2).

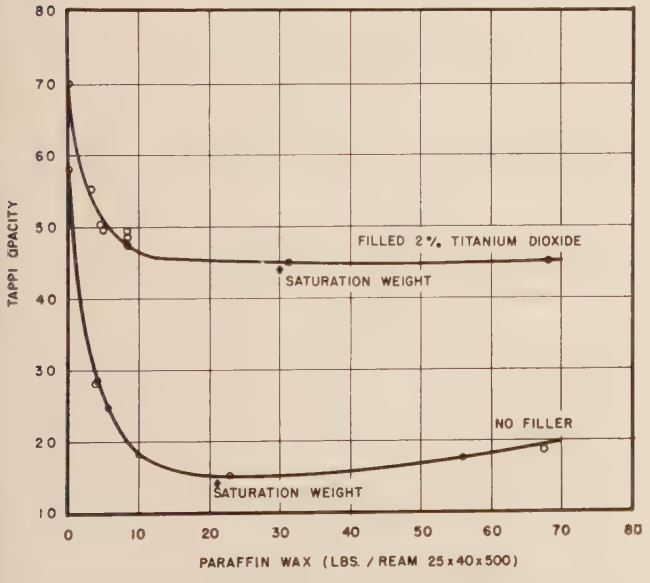

Fig. 2. Determination of wax saturation weight; 25 lb. bleached sulphite (25 × 40—500); paraffin 100°C.

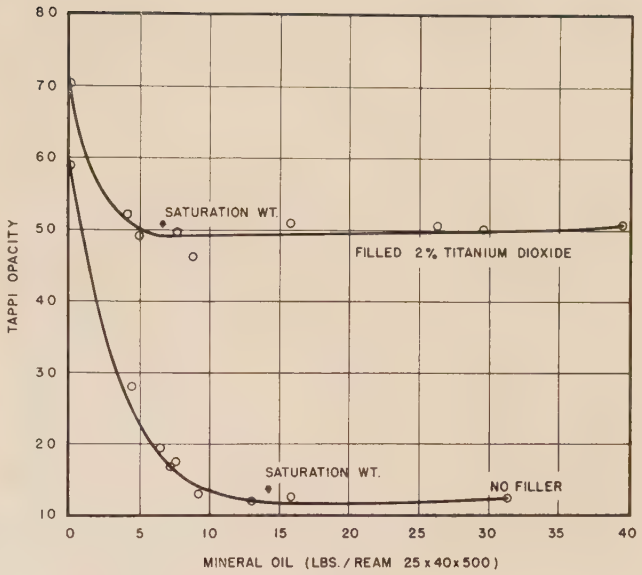

Fig. 3. Determination of mineral oil saturation weight; 25 lb. bleached sulphite (25 × 40—500); oil 100°C.

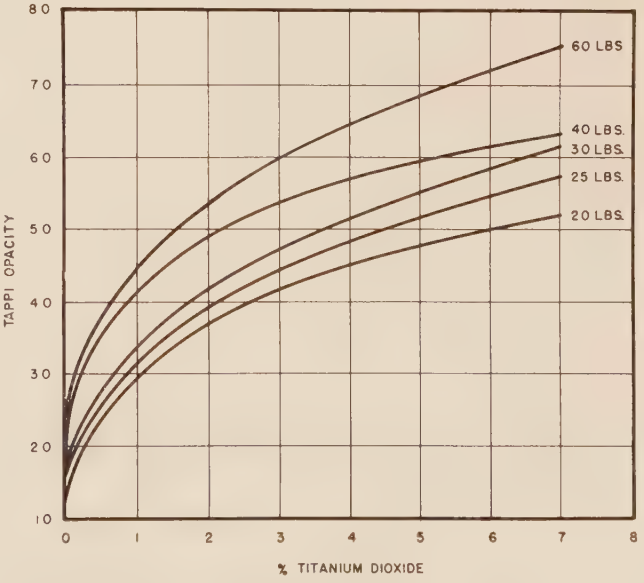

Fig. 4. The effect of basis weight change on the estimation of titanium dioxide by waxed opacity; bleached sulphite; 2% alum; no size; paraffin 100°C.

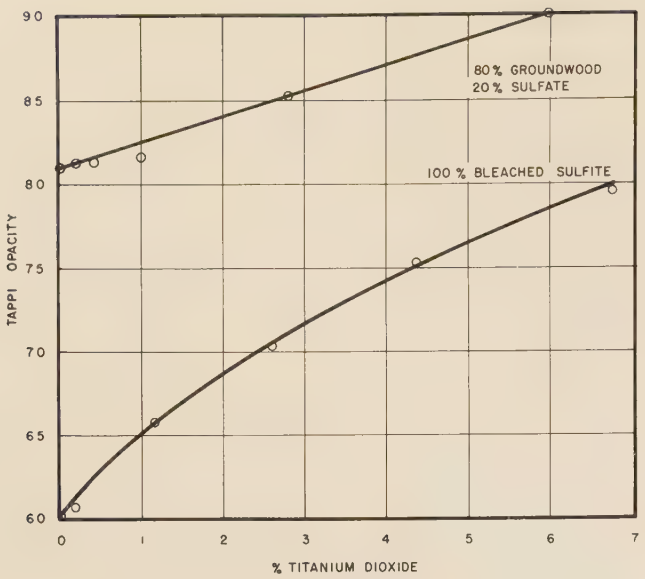

Fig. 5. Effect of groundwood pulp on dry opacity; 25 lb. (25 × 40—500) handsheets; 2% alum; no size

Mineral oil has very little opacity (see Fig. 3) and paper is readily impregnated with it. However, the impregnated paper is messy to handle and to determine oiled opacity.

Immersion Time for Paper Saturation. The paper to be tested must be thoroughly dried just seconds before immersion in the constant temperature wax bath. This is very important since a little water in the paper will prevent the wax saturation of the sheet. The importance of thorough drying increases as the basis weight of the paper is increased. The minimum immersion time for paper saturation is determined by immersing the paper to be tested in a constant temperature wax bath for various intervals of time and testing each sheet for waxed opacity (T 425 m-44). It will be found that the waxed opacity value will reach a minimum constant value after immersion for a given time interval in the hot wax. This time interval is the minimum immersion time to secure saturation of that particular

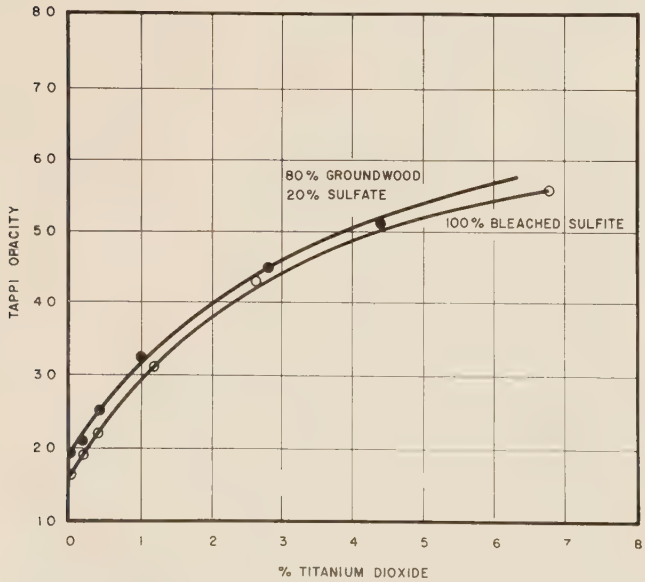

Fig. 6. Effect of groundwood on waxed opacity; 25 lb. (25 × 40—500) handsheets; 2% alum; no size; paraffin 100°C.

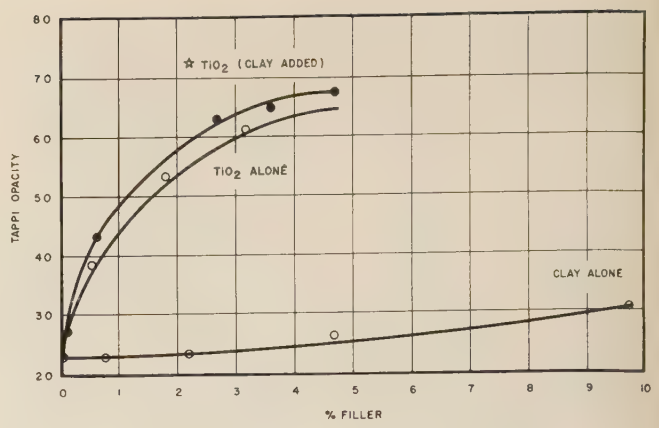

Fig. 7. The effect of filler clay on the estimation of titanium dioxide by waxed opacity; 60 lb. basis weight (25 × 40—500) bleached sulphite; 2% alum; no size; paraffin 100°C.

☆ Constant 60% clay addition; variable TiO_2 addition.

type of paper. This value will vary with the paper density, caliper, basis weight, pulp type, sizing, and wax temperature. It is recommended that the actual time interval used in practice be one and one-half times the minimum immersion time, since excess immersion does not cause an error in the determination. Instead of using the minimum waxed opacity of the sheet as a guide to the minimum immersion time for saturation, it is also possible to determine the wax addition by weighing the sheet before and after immersion. When the waxed opacity reaches a constant value, the paper saturation point has been reached. Figures 2 and 3 show the wax and oil add-on plotted against the opacity. The method described in TAPPI Standard T 467 m-48 may also be used to saturate the paper but it is somewhat more time consuming than the above method.

Determination of Waxed Opacity

The opacity of the oiled or waxed sheet after saturation should be run according to the TAPPI Standard T 425 m-44. Under this method, the operator should wax or oil at least five specimens and average the opacity results for one point on the graph. Five well-

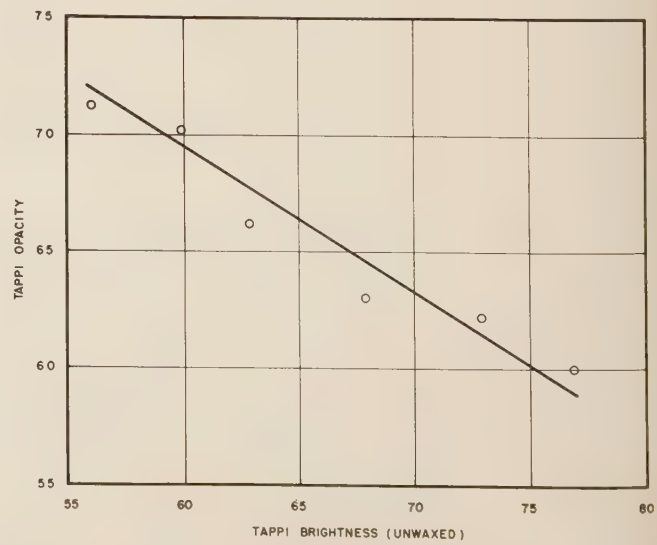

Fig. 8. The effect of brightness change on the unwaxed opacity of paper; 25 lb. (25 × 40—500) bleached sulphite; 2% alum; no size; dye used, Nigrosine WSB

chosen points are adequate for a graph of reasonable accuracy. Once a graph has been established for a given type of paper, the titanium dioxide content of a given sample may be estimated readily from the waxed or oiled opacity figure.

VARIABLES AFFECTING WAXED AND OILED OPACITY OF PAPER

Degree of Saturation

It is necessary that the paper tested for opacity be completely saturated with wax or oil and the air removed or the operator will report a titanium dioxide content in excess of the true value (Figs. 2 and 3). Where paraffin is used, care must be exercised that the excess surface film of wax is removed with rolls or knives or the operator will also report a titanium dioxide content in excess of the true value. This difficulty is not critical when the titanium dioxide content reaches 2% and is not a factor with transparent impregnants such as mineral oil (see Figs. 2 and 3).

Basis Weight

Titanium dioxide is normally added and analyzed for on the basis of weight per cent. Since paper is made in various calipers which is roughly proportional to weight, it will contain more titanium dioxide, at a given per cent, in a square inch of paper of 50-lb. basis weight than a similar paper of 20-lb. basis weight. Therefore, the waxed opacity of a 50-lb. paper containing 1% titanium dioxide will be greater than a similar 20-lb. paper with the same percentage of titanium dioxide. Figure 4 shows graphs of the waxed opacity versus titanium dioxide content of a bleached sulphite paper at various basis weights. It is interesting to note that the waxed opacity of the bleached sulphite fiber alone increases from 13% at 20-lb. basis weight (25 × 40—500) to 23% at 60 lb. The presence of 1% TiO_2 causes an increase in waxed opacity of 15% at 20-lb. basis weight to 22% at 60 lb. This large change in the opacity reading at the low and more common titanium dioxide contents holds the relative error of the estimation low in this vital portion of the curve.

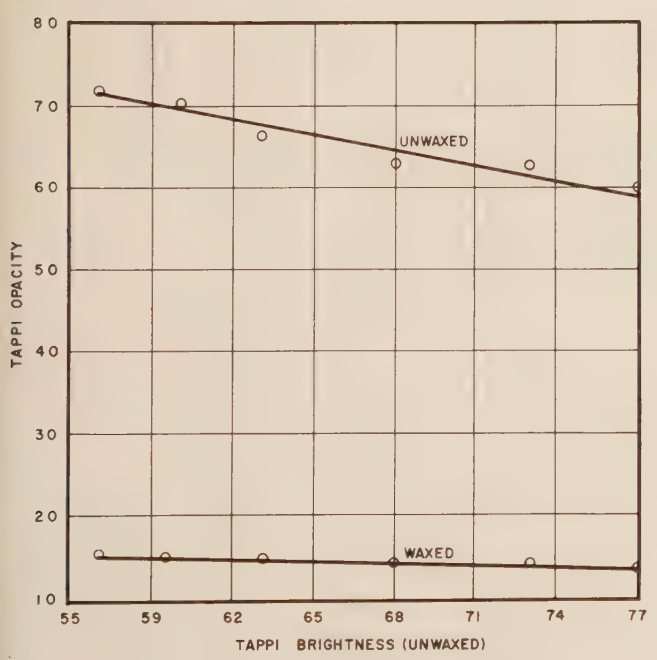

Fig. 9. The effect of brightness change on the opacity of paper; 25 lb. (25 × 40—500) bleached sulphite; 2% alum; no size; paraffin 100°C., dye used, Nigrosine WSB

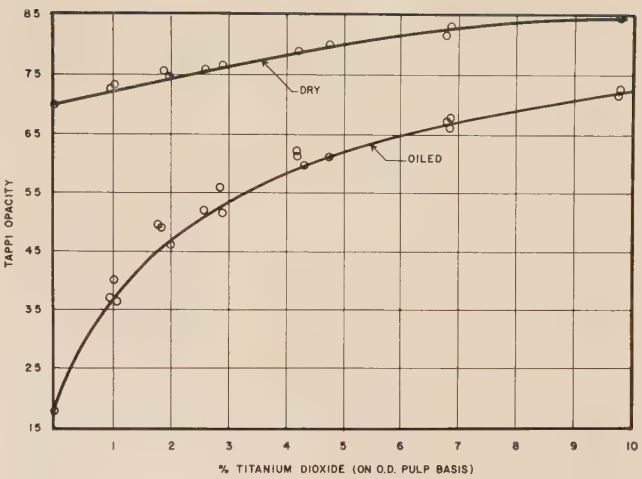

Fig. 10. Dry and oiled opacity; 30 lb. (25 × 40—500) bleached sulphite; handsheets; mineral oil 100°C.

Effect of Groundwood Pulp

Groundwood pulp is often blended with other pulps to produce paper with a higher dry opacity. A comparison of the TAPPI opacity of two papers, one with and one without groundwood, is shown in Fig. 5. However, when the same papers are saturated with paraffin wax and the opacity determined, the graph shown in Fig. 6 is obtained. This indicates that the groundwood imparts very little waxed opacity to a paper and the amount is sufficiently small to be ignored for most estimation purposes.

Effect of Clay Filler

The use of clay filler in the beater along with the titanium dioxide is widely practiced in the paper industry. In many mills, it is present in larger amounts than the titanium dioxide; and, under these conditions, it is a source of some error in the present analytical methods for determining titanium dioxide in paper. Most filler clays contain titanium to the extent of 1 to 4% (calculated TiO_2) in a mineral form that has no pigment value. Present analytical procedures for determining titanium dioxide pigment in the paper give the total titanium dioxide content. Therefore, the analyses for pigment titanium dioxide are always slightly higher than the actual, when clay is present. The waxed opacity method of estimating titanium dioxide, however, is not affected by this titanium in the clay if the analyses used in making the reference graph are corrected for this error. Figure 7 shows that the presence of clay should cause very little error to the waxed opacity method of estimating titanium dioxide.

Effect of Brightness Change

Numerous investigators (*2*) have observed that dyes and other light-absorptive materials which lower the brightness of paper will increase the dry opacity of the paper. Figure 8 shows a typical example of this phenomenon and it was prepared by dyeing 25-lb. (25 × 40—500) handsheets with Nigrosine WSB from a brightness of 77 to 56%. The opacity increased as a result from 60 to 71%. However, when the same

Table I. **Probable Error Oiled Opacity Method of Estimating Titanium Dioxide**

30 lb. (25 × 40—500) bleached sulphite handsheets—mineral oil 100°C.

Sample No.	*TiO_2 content by gravimetric ash analysis, %*	*TiO_2 content by oiled opacity, %*	*Relative error, %*
1	0.57	0.61	7.0
2	0.57	0.59	3.5
3	0.57	0.59	3.5
4	1.98	1.9	4.0
5	1.98	2.0	1.0
6	2.63	2.9	10.3
7	2.63	2.8	6.5
8	4.70	5.1	8.4
9	6.86	7.3	6.4
10	6.86	7.0	2.0
11	6.86	6.6	3.7
12	9.80	9.8	0.0
13	9.80	9.6	2.0
Maximum relative error			10.3
Average relative error			4.5

sheets are waxed with paraffin, the opacity change is 13.6 to 15.3%, Fig. 9. In plant operation, a brightness variation of 21% is very unlikely but this caused a waxed opacity change of only 1.7%. Therefore, brightness changes due to transparent light-absorptive materials should not cause an appreciable error in the estimation of titanium dioxide content of paper by waxed opacity. This statement should not be interpreted as covering conditions where colored pigments are present in the beater. Titanium dioxide is seldom used with colored pigments and this particular condition is not covered in this paper.

ACCURACY OF THE METHOD

Some idea of the accuracy of estimating titanium dioxide by the oiled or waxed opacity method was considered necessary. A laboratory assistant with no previous analytical training or chemical education was selected. He was supplied with a graph and a sufficient amount of handsheet paper for 13 different determinations of titanium dioxide by the oiled opacity method. Portions of this paper had already been analyzed for pigment by ashing and weighing. The results are compared in Table I. It will be noted that the maximum relative error of these 13 determinations was 10.3% and the average relative error was 4.5%. The per cent of titanium dioxide present in the papers varied from 0.5 to approximately 10.0%. The graph used for this evaluation is shown in Fig. 10.

SUMMARY AND CONCLUSIONS

There is a need in the paper industry for a simpler and faster method of estimating the anatase titanium dioxide (beater added) in a sheet of paper. The author suggests a method based on the waxed or oiled opacity of the paper. The method consists of:

1. The preparation of a graph for each grade of paper; the graph to show a curve prepared by plotting the saturated waxed or oiled opacity against the titanium dioxide content of the paper.
2. The sample to be tested is oiled or waxed a minimum immersion time at similar temperature to the papers used in making the graph, and the opacity (T 425 m-44) determined. This value may be changed to titanium dioxide content by means of the previously prepared graph.

Data are shown indicating that separate graphs must be prepared at each basis weight.

The method is shown to be applicable to furnishes containing clay or groundwood pulp.

Sizable changes in the brightness of the furnish may occur without appreciably affecting the waxed opacity and the accuracy of the test.

An experiment with untrained personnel using the oiled opacity method of titanium dioxide estimation on 13 papers gave a maximum relative error of 10.3% and an average relative error of 4.5%.

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The Utilization of Knots and Screening Rejects in Bleached Kraft Pulp

A. L. WILEY, N. R. PHILLIPS, and E. A. HENRY, JR.

The development of a knot and screen reject recovery system for the reclamation of bleachable kraft fiber is described. The system consists of mechanical crushing and refining operations followed by Bauer cleaners and flat screens. It has been found that the accepted fiber from this type treatment produces a bleachable grade of kraft pulp, and that its use has no effect on quality.

One of the interesting problems in the manufacture of high-quality bleached kraft pulp is the utilization of knots and screening rejects in such a manner that this type of material will not adversely affect the quality of the finished pulp.

Important savings of fiber can be made by recovering knots and rejects. These materials in themselves represent a substantial quantity of fiber and they carry with them an additional quantity of good fiber which the screens failed to accept. If production is limited by the digesters or the liquor recovery system, the recovery of the rejects by mechanical treatment becomes particularly important economically because it makes increased production possible with a consequent cost reduction.

A. L. Wiley, N. R. Phillips, and E. A. Henry, Jr., Riegel Carolina Corp., Acme, N. C.

During the past several months, Riegel Carolina Corp. has developed and put into operation two separate systems for the recovery of knots and screening rejects. In this paper the authors will outline the physical layout of these systems and discuss the results which have been obtained.

The knot reclaiming system that has been installed at Riegel Carolina will be seen in Fig. 1. The knots from the deknotter screens ahead of the brown stock washers pass down through an angular knot hopper into a type A Jeffery hammermill equipped with $^5/_8$-in. plates. From the hammermill, the knots flow by gravity into a conical bottom tank from which they may be pumped to a digester blow tank.

Several checks on the knot system have shown that the material that will pass through this system will vary from 1.5 to 4.0 air-dry tons of stock per day for approximately 300 air-dry tons of pulp production. It has been found that the material that is discharged from the hammermill is well broken. This system requires approximately 7 hp.-days per ton of material passed through the hammermill and pumped to the blow tank. From the blow tank, the defibered knots pass with the pulp from the digesters to the brown stock washers and thence to the flat screens. Any of the defibered knots which are rejected by the flat screens pass into the screen reject recovery system.

Data compiled from operating reports indicate that material from the knot system when added to the blow tank has had no effect on the brightness, dirt content, bursting strength, tear, and bleach chemicals required for bleached kraft pulp.

Summarizing the results to date with the knot system, knots from the hammermill have satisfactorily been used with no deleterious effects on the bleached

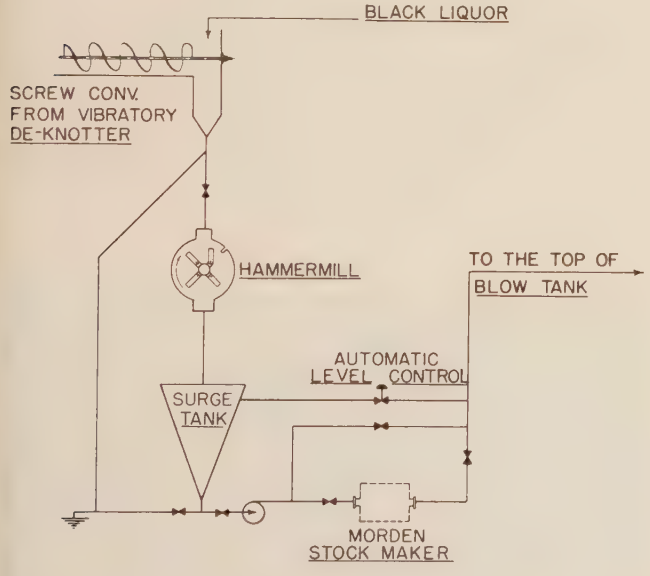

Fig. 1. Knot system

kraft pulps. Because of recent increases in production, the company is now planning to supplement the hammermill by installing a Morden refiner in series with it.

SCREENING REJECT SYSTEM

Figure 2 represents the physical layout for the reclamation of screening rejects. The rejects from the kraft tailing screens pass to a storage tank from which they are pumped to a constant flow headbox. The stock flows from the headbox over a drainer conveyor that feeds a 36-1 Sprout-Waldron refiner. Stock from the refiner drops into a storage chest from which it is

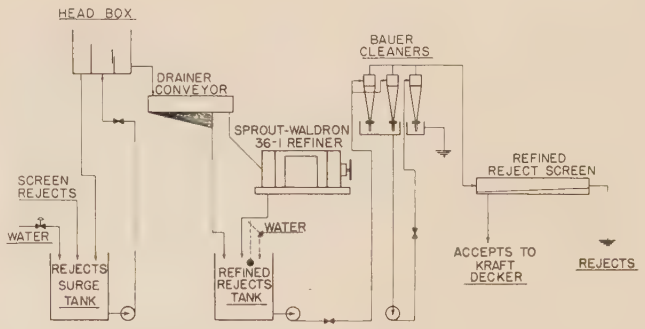

Fig. 2. Screening reject system

pumped to two primary 12 by 2 by 2-in. Bauer cleaners. The primary cleaner rejects pass through a secondary 12 by 2 by 2-in. Bauer cleaner and rejects from the secondary are sewered. The accepted stock from the primary and secondary cleaners flow to a small 14-plate reject screen that has seven 10-cut and seven 12-cut plates. The accepted stock from the rejects screen flows to the kraft decker, and the screen rejects go to the sewer.

It has been found from actual operating data that the flow in this system will vary from roughly 3 to 7 air-dry tons of material per day for approximately 300 tons of daily production. The screening reject reclamation system described above works efficiently and requires about 15 hp.-days per ton of material handled.

No effect on the quality of the bleached pulp as a result of using the refined screen rejects has been noticed. The bleach plant consists of six stages, namely, chlorination, extraction, hypochlorite, extraction, hypochlorite, and chlorine dioxide. There has also been no noticeable increase in the quantity of bleaching chemicals required to bleach the pulp when material from the screening reject system has been added. It is believed that a satisfactory and easily operated layout for reclaiming screen rejects has been installed.

CONCLUSIONS

Experience has indicated that it is possible to recover knots and reuse them in the manufacture of bleached kraft pulp with no effect on the quality of the finished pulp.

The reclamation of screen rejects has proved to be entirely practical in the manufacture of quality bleached pulp. The inclusion of this type of material from the reject reclaiming system has had no effect on pulp quality or bleaching chemicals.

It is believed that the recovery of knots and screen rejects is practical in the manufacture of quality bleached kraft pulp and represents a substantial saving of fiber and an opportunity to increase mill capacity.

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Study of Paper Composition by Parallel Sectioning

B. L. BROWNING and I. H. ISENBERG

In many technical problems concerned with paper structures and properties, it is desirable to know the distribution of size, filler, and other components through the thickness of the sheet. Similar questions arise in studies of penetration of coatings and tub sizings into the base sheet. For several years, the Institute laboratories have used a method based on parallel sectioning of the paper followed by analysis of the prepared sections using suitable microtechniques. Typical applications are illustrated in this paper in the belief that they may be of general interest.

Previous methods of sectioning have been utilized mainly for determining filler distribution in paper. Approximate methods have been based upon splitting the sheet into top and bottom sections after adhesion between gummed kraft papers (*1*), or of scraping off successive layers of paper with a razor blade (*2*). Schilde (*3*) devised an apparatus in which successive zones of the paper could be removed by scraping with a razor blade. The successive layers removed were collected and analyzed for ash.

A technique based on abrading the surface of the paper with emery cloth has been used (*1*). The amount removed was determined by micrometer measurement. After removing the top third from one strip and the bottom third from another, ash determinations gave the filler content in the top, middle, and bottom of the sheet. Schütz (*4*) found the filler content in the top and bottom of sheets by grinding off the undesired portion with Carborundum paper. Hansen (*5*) also used Carborundum paper in abrading paper to determine filler distribution. Portions of the paper abraded to various depths were ashed, and the results permitted calculations of the ash content at each point through the sheet. Dappen (*6*) used a mechanical erasing device in studying starch and clay distribution in paper coatings.

It has been found possible to prepare microtome sections of paper in the plane of the sheet. The sections so obtained are satisfactory for use in microanalysis to determine the distribution of size or filler through the sheet. The techniques are generally applicable, and the sections isolated are more precisely defined than those procured by procedures based on scraping or abrading the paper surface.

PROCEDURE FOR PARALLEL SECTIONING

A sliding microtome is used for the sectioning. It is necessary that the paper be held flat and in the plane of movement of the cutting knife. A small (about 20 by 15 by 10 mm.) block of white pinewood (any wood soft enough to cut easily may be used) is placed in the specimen holder of the microtome so that tangential sections are cut. The wood block is leveled smooth by the necessary number of cuts with the knife. A small (5 to 10 by 10 to 15 mm.) piece of the paper is mounted on the block by means of Duco cement, with the long direction of the paper parallel to the long direction of the block (Fig. 1). The paper is pressed firmly and evenly on the wood until the cement has dried.

Before sectioning, the specimen is lowered by a distance equal to the thickness of the paper and the cement. Next the block is raised by 5-mu increments until the knife just grazes the surface of the paper. Then the block is raised the desired amount for the section (usually 15 to 20 mu) and the first section is cut. The section is removed by a camel's hair brush to a suitable container. Successive sections are removed by raising the block the desired amount and cutting in the same way.

It is difficult to cut sections thinner than 15 mu, but for a paper 4 mils in thickness this permits separation into six or seven layers. It is possible to cut somewhat more than half the thickness of the sheet before encountering the adhesive. The opposite side of the sheet is then sectioned in a similar manner but using another specimen.

No difficulty has been experienced in sectioning sheets either with or without filler. Sectioning of papers tub-sized, as with starch, is also satisfactory. In coated papers, the microtome knife sometimes rides over the surface or cuts below the coating, so that it is difficult to cut the coating layer into sections of precisely the thickness indicated by the microtome setting.

If the nature of the paper is such that even and uniform sections can be cut, the location of the section in the paper may be established by the microtome settings during sectioning. If there are appreciable differences in hardness or resistance of the paper in different zones, it may be necessary to determine the amount of paper removed not by the microtome setting but by weighing the sections removed on a microbalance. In this case

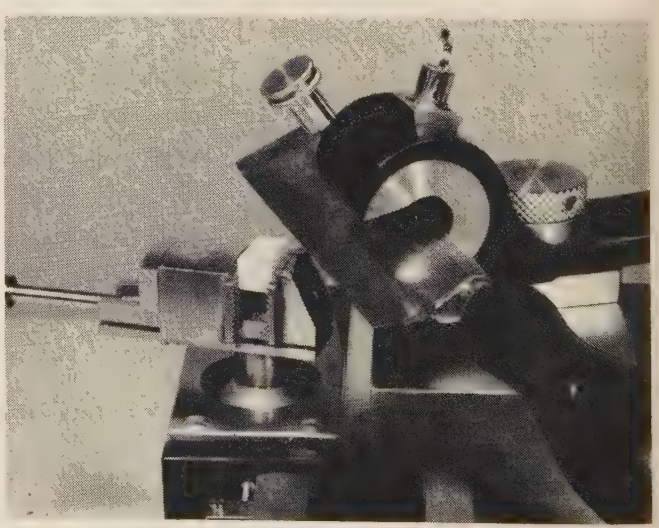

Fig. 1. Sliding microtome with paper in position for sectioning

B. L. Browning, Research Associate, and I. H. Isenberg, Research Associate, The Institute of Paper Chemistry, Appleton, Wis.

the determined distribution of any constituent must be based on percentage of "weight thickness," rather than upon the linearly established position of the section. Generally, a number of corresponding sections from separate but contiguous portions of the paper (about five to ten) are combined as a composite sample, both to secure a specimen large enough for analysis and to assure a more representative sample.

DETERMINATION OF FILLER DISTRIBUTION

The application of the sectioning technique to the study of filler distribution may be illustrated by examination of a commercial sheet. The paper was a sulphite-groundwood sheet 90 mu in thickness and containing about 22% clay filler.

Four sections each of 15 mu thickness were cut from the wire side of the sheet and four from the felt side. Ten specimens selected randomly were used in sectioning from each side of the sheet. The corresponding sections (the ten first sections from the felt side, etc.) were united to form a composite sample. The samples were weighed on a microbalance, ashed, and the weight of ash found.

The data are plotted in Fig. 2. It is assumed that each section is 15 mu thick, and the ash content of each of the groups of sections cut from each side of the sheet is plotted at the average distance of the section from the felt side of the sheet.

The average ash value of the paper calculated from the ash content of sections is 18.4%. The ash content determined on the whole paper was 19.2%.

DETERMINATION OF STARCH DISTRIBUTION

The distribution of starch may be of interest when starch is added to the beater, or in studies involving the penetration of starch when it is applied as a tub size or as the adhesive in a coating formulation. The

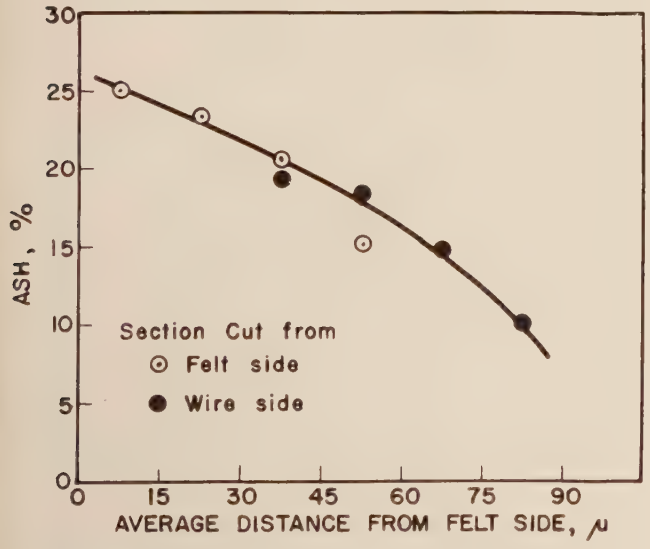

Fig. 2. Distribution of ash in a clay-filled paper

determination of size distribution in paper is shown by an example of starch penetration from a starch coating.

The distribution of starch in a sheet coated in the laboratory with a starch-clay coating is shown in Fig. 3. The total thickness of the coated sheet was approximately 90 mu. Apparently, a small amount of starch was picked up on the uncoated side during the coating operation.

In order to determine starch in the small quantities available in the sections, a modification of the colorimetric method of Browning, Bublitz, and Baker (7) was used. The sample in each case was a composite of

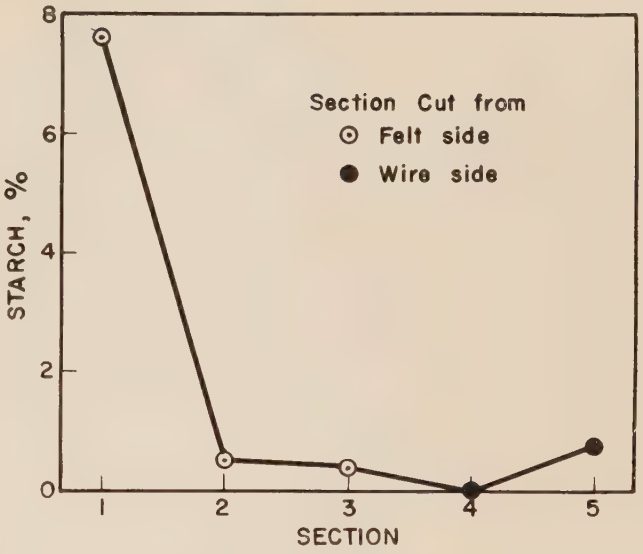

Fig. 3. Distribution of starch in a coated paper

ten corresponding sections. The sample was weighed, placed in a 30-ml. beaker, and 10 ml. of hot water were added. The beaker was placed in a boiling water bath and the paper was macerated with a stirring rod. After 30 min., the extract was decanted through a micro Gooch crucible with asbestos mat (using light suction) and the filtrate was received in a 50-ml. volumetric flask. The residue was washed with a few milliliters of hot water. The residue was retained in the beaker and extracted successively with two 5-ml. portions of 21% HCl for 3 min. each and with two 2-ml. portions of concentrated HCI for 20 sec. each. Finally, the extracted paper was transferred to the crucible and washed with a few milliliters of hot water, 1 ml. of iodine reagent was added to the flask and the flask filled to the mark with water. The transmittance of the solution was measured at 580 mmu, using for a blank the iodine reagent and hydrochloric acid in the same concentration as in the unknown. The quantity of starch was determined from a calibration curve determined similarly but using known quantities of starch.

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Utilization of Kraft Knotter Rejects

RALPH E. MILLAR, Jr., JAMES M. PIETTE, and JOHN J. OWEN, Jr.

The utilization of pulp screen rejects has presented problems in the operation of all pulp mills. This paper describes the methods that the Savannah plant of Union Bag & Paper Corp. has used to handle these rejects, particularly knotter rejects. Originally knotter rejects were fiberized with tailings from the fine screens and used in the bottom board sheet. However, inability to use all the knots in this manner resulted in rather high fiber losses at times. Consequently, the recooking of knotter rejects, first with chips and then alone, was begun. The rejects handling system and the cooking conditions for recooking knots are described. Data are given correlating yield, per cent chemical, and permanganate number for experimental rejects cooks. Cooking the rejects with the chips produced acceptable pulp but there was a tendency to a buildup of knots. Separate cooking produces a pulp at a 65% yield at 33 permanganate number.

In the production of pulp for the manufacture of linerboard, bags, and specialty papers, it is necessary that incompletely pulped chips be separated from the acceptable pulp by screening. The screening or rejects, the quantity of which depends on cooking conditions and product, present problems of varying degree in the operation of all pulp mills.

Valuable papermaking fiber is lost if any part of the rejects is simply discarded as has been the practice at some mills. Such procedure also places a heavy load upon the mill disposal system. This useful fiber may be recovered by mechanical fiberization or by recooking of the rejects and subsequent blending with the regular furnish to the paper machines, or by a combination of the two methods. The choice of method is dependent upon operating conditions at the individual mill and the economic situation in general.

This paper is a discussion of the steps that the Savannah plant of Union Bag & Paper Corp. has taken to meet the problem of utilization of rejects.

After washing, our pulp undergoes two stages of screening, first in the coarse screens or knotters, then in the fine screens. Impco knotters are used with 0.5-in. perforations in stainless steel plates. Accepted stock from the knotters goes to the fine screens which are equipped with plates with 0.100-in. perforations for multiwall stock and with 0.125-in. perforations for other pulps. Rejects, or tailings, from the fine screens are given a further screening in the tailings screens which have plates with 0.125-in. perforations. The rejected knots and tailings from these operations make up the rejects that should be utilized.

There have been no major changes in the basic methods of handling tailings or rejects from the fine screens since the start-up of the Savannah plant. All tailings are mechanically fiberized and returned to the papermaking system for blending with the furnish for the primary board sheet. This procedure is similar to that in use in almost all kraft mills today, therefore, a detailed description of the operations involved in handling tailings will not be given.

A flow diagram of the rejects handling system is shown in Fig. 1. Tailings from the fine screens are collected in the rejects chest, dewatered on a Woods thickener to an average consistency of about 9%, fiberized in two Bauer and two Sprout-Waldron refiners in parallel, then returned to the knotter headboxes of the board machines.

Prior to 1950, knotter rejects were also refined and blended with the pulp making up our board sheet. Mechanical fiberization of knotter rejects for use in board production presents a somewhat different problem than does the use of refined tailings. Fiberization of knotter rejects produces darker, coarser pulp with lower strength properties than that obtained from fine screen rejects. Therefore, the papermaker must apply greater discretion in his use of knots. Our paper mill has also reported difficulty in drying a sheet containing a large percentage of refined knots.

The system used for handling the knotter rejects prior to 1950 is shown in Fig. 1 together with the tailings system. Before being fiberized, knots were passed over a flat screen with 0.020-in. slots to separate useful fiber which was returned to the knotter headboxes. The amount of fiber varied with the load on the screens and usually ranged from 10 to 20% of the total knotter rejects. The knotter rejects were then broken up in a Gruendler hammer mill refiner and passed into the rejects chest where they were mixed with the tailings, and then dewatered and fiberized.

The utilization of rejects was limited by two factors: the type of production and board quality requirements. Since it was not feasible to use refined rejects in the production of paper, all rejects had to be discarded when none of the machines were producing board. When the added losses due to mechanical failure are considered it becomes apparent that the loss of rejects was quite high at times.

Rejects losses became increasingly greater as pulp production increased, the ratio of board cooks to paper cooks grew, and the bursting strength requirements for board increased. Finally, in 1949, it was decided to discontinue refining knotter rejects and begin cooking them with fresh chips.

A previous investigation had been made of the possibility of recooking knots and the results appeared promising. Knotter rejects were placed in small baskets and cooked with wood chips in mill digesters producing pulp for board production. The pulp was taken from the baskets after the blow and beater evaluations were made on this stock as well as on pulp from the digester blow. In addition, tests were made on fiberized rejects from the Bauer refiners.

The results of the tests were quite informative. It

Ralph E. Millar, Jr., Engineer, Mill Technical Department, James M. Piette, Pulp Mill Superintendent, and John J. Owen, Jr., Group Leader, Mill Technical Department, Union Bag & Paper Corp., Savannah, Ga.

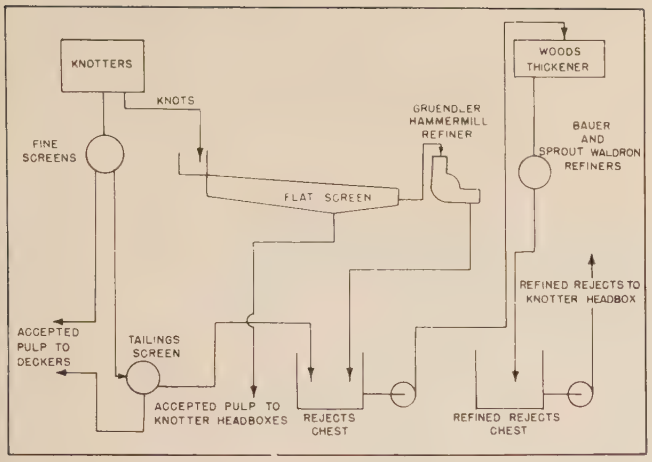

Fig. 1. Rejects system for refining knots and tailings

was found that the bursting strength test for recooked knotter rejects is only slightly lower than that for regular board pulp while the tear is higher. A similar comparison for recooked rejects with mechanically fiberized rejects shows recooking to result in substantially higher burst and tear tests. Pulp yield from pulping of knotter rejects along with chips in regular board cooks averaged about 61%.

The necessary modifications to the rejects system were made and early in 1950 the recooking of knotter rejects was initiated. The revised rejects system, in which knots were mixed with the chips to the chip bin, is shown in the flow diagram of Fig. 2. Note that the changes included the removal of the Gruendler refiner. The chest in which refined rejects were formerly collected is now used for the separate collection of knotter rejects. Knots from this chest initially were passed ever a dewatering screen, then to the chip conveyor belt via a bucket feeder system.

No detrimental effects on pulp quality were noted as a result of recooking knotter rejects and the loss of rejects was decreased considerably to about 20% of the average losses during the 13 months prior to the beginning of rejects recooking.

Unfortunately, the economic picture was not quite as bright as it appears at first glance. The basket cooking of knotter rejects had shown a probable pulp yield of 61%, but a yield of about 95% can be anticipated from the mechanical fiberization of rejects. This difference of over 30% in yield is a loss which, of course, must be considered and which narrows the breach between the old and the new reject losses.

It is probable, then, that there was little direct economic gain resulting from recooking knotter rejects rather than refining them and taking the losses which sometimes occurred as mentioned. However, a better quality pulp was produced from the rejects, a fact of considerable importance in the production of a high quality board. Disposal problems were also eased as the quantity of rejects to be disposed of was reduced.

There were still occasional rejects losses due to overloading of the rejects handling system. In view of this and the fact that a higher yield can be obtained from refining rather than recooking knotter rejects, an investigation was instigated to determine the quantity of refined knots that could be used in the board sheet without impairing quality.

Several trial runs were made in which up to 25% of the knotter rejects, about 15 tons, were refined and used in the bottom board sheet. This quantity of knots represented about 3% of the furnish to the board machine. The limited capacity of the reject handling system prevented the use of a greater percentage of refined knots. There was no indication that board quality was impaired in any way during these trials.

For a number of months, approximately 10% of the knotter rejects were fiberized and used in board production. This procedure placed such a load on the reject refining system, however, that it soon became apparent certain changes would have to be made to continue to refine knots. The alternative was to cease fiberizing knotter rejects and recook all knots.

Recooking rejects, while giving a lower yield than refining, offered much less danger of affecting board quality, consequently it was decided to enlarge the capacity of the reject recooking system.

The major change in the system was the installation of a Rotolift conveyor as replacement for the bucket feeder that had been used for conveying knotter rejects to the chip belt. Operation of the bucket feeder had never been completely satisfactory, rejects tended to pack in the buckets so that they failed to empty completely, thus further reducing the capacity of the system. With the Rotolift in operation, the enforced discarding of knotter rejects as a result of overloading was materially decreased.

There is little doubt that rejects, which have been through the cooking cycle, do not cook in the same manner as do fresh wood chips. A less severe cook than that given chips should result in a higher total yield from knotter rejects. Too, a stronger pulp should be produced if excessive degradation of the cellulose is not allowed in the second cook. There also was some evidence that the cooking of a mixture of knots and chips caused a buildup of knots in the system necessitating periodic disposal of the excess. In the interest of obtaining a more uniform pulp and higher yield from cooking of rejects, and possibly reducing the quantity of rejects to be handled, an investigation was started on both a laboratory and mill scale to determine the practicability of making separate knot cooks.

A series of cooks of knotter rejects was made in the pulping laboratory experimental digester. By varying cooking conditions total yields of 57 to 68% and screened

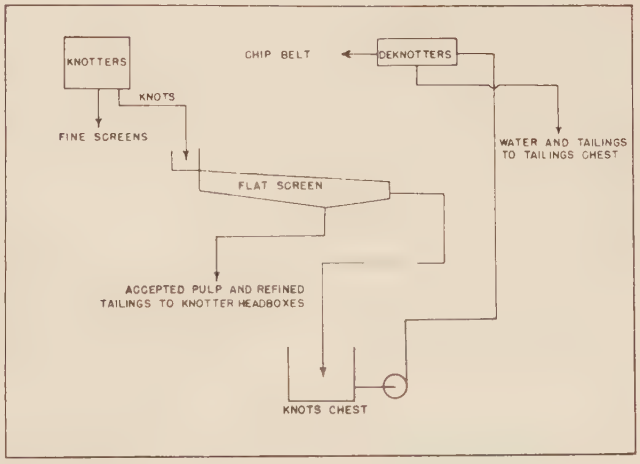

Fig. 2. Rejects system for recooking knots with chips

yields of 56 to 64% were obtained at permanganate numbers of 21 to 34. These data are plotted in Fig. 3 which shows permanganate number versus total yield and versus total alkali.

Test results indicated that the strength properties of pulp from recooked rejects were lower than those of pulp from regular cooks, but substantially higher than those of pulp from refined knotter rejects. Color of the handsheets was only slightly darker than that of sheets from regular pulp. The color and lower strength properties were of no great concern considering the relatively small amount of this pulp that would be blended with the regular stock.

At this time, several experimental cooks of knotter rejects only were made in mill digesters. The first of these were not particularly successful due evidently to excessive dilution of the cooking liquor by the water remaining with the rejects. When the digester drain valve was left open during filling, allowing considerably more dewatering of the charge, better pulping was achieved. Two small vibratory dewatering screens were installed in parallel just before the loading conveyor to the digesters. Consistency of the knots was increased from about 3% to 20 to 25% before entering the digesters. Further dewatering occurs through the digester drain valve as the rejects are compressed while loading.

The results of these experimental cooks indicated that it would be preferable to cook knotter rejects separately rather than with fresh chips. Consequently, the rejects handling system was modified to allow this to be done. The only changes necessary were the installation of the dewatering screens and the replacement of the Rotolift by a belt conveyor to the digesters. Drainage from the screens is returned to the Woods thickener for recovery of fiber. The conveyor is installed so that it can be swung easily to load any one of the three digesters that are used for cooking rejects.

The rate of loading rejects in the digesters depends on the rate of production of knots since there is virtually no storage space in the system. Actually, the flow is continuous from the knotters to the digesters, with a very slight retention time, possibly 7 to 9 min., in the knots chest. When the ratio of board pulp to paper pulp is decreased, of course there are fewer rejects and a longer time is required to charge a digester. During

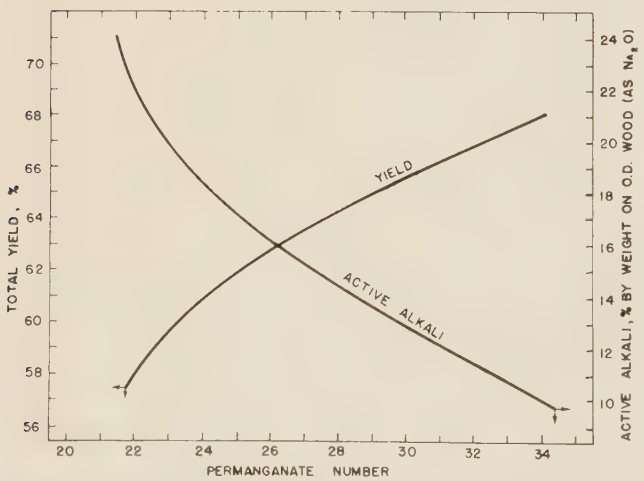

Fig. 3. Permanganate number versus total yield and chemical concentration

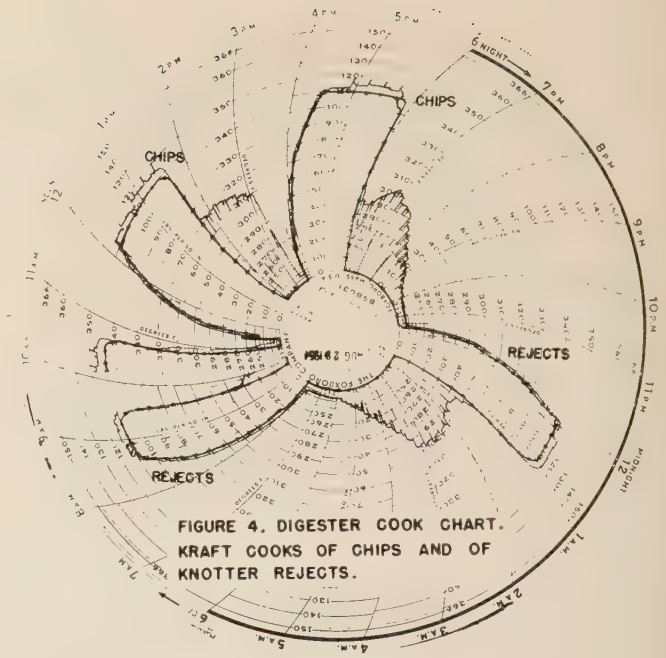

Fig. 4. Digester cook chart; kraft cooks of chips and of knotter rejects

these periods of low reject production, rather than keep digesters idle, regular cooks or fresh chips are made.

Digesters are not charged full of knots as they are with chips. Because of the higher yield from rejects, in the neighborhood of 65% a fully loaded digester would blow considerably more pulp into a diffuser. Since this would make for nonuniformity in diffuser operation, it has been the practice to charge only enough knotter rejects to produce approximately the same quantity of pulp as the normal chip cook.

The knotter rejects, as charged to a digester, are partially delignified and still impregnated with some soda; consequently, a lower soda charge and less rigorous cooking conditions are applied to these cooks. A constant volume of cooking liquor, averaging about 75% of the normal charge with chips, is used in each knot cook regardless of the activity of the liquor. No black liquor make-up is used.

The cook is brought to pressure as rapidly as possible, usually in about 40 or 45 min. then held at pressure for approximately 45 min. Since the volatile material remaining in rejects is negligible, very little relieving is required and this is done to the atmosphere.

The digester chart in Fig. 4 shows two typical knotter rejects cooks as well as two regular cooks. Note that the cooks are all to the same pressure, 110 lb., but the total time of each knot cook is only about 90 min. compared to 2 hr. for the regular cooks. The time required to charge the digester with rejects for these cooks was from 5 to 6 hr.

Rejects are generally cooked to a permanganate number of about 33, slightly less than the average for our board cooks. The pulp, after the blow, is washed in diffusers and blended with the regular furnish to the board machines.

Cooking knots separately has apparently eliminated the build-up of knots in the system that was experienced when knots and chips were cooked together, and periodic discarding of knots is no longer necessary.

It is probable that still further revisions will be made

in the rejects-handling system. A study of more advantageous means of utilizing rejects is being made. One possibility is as a replacement for the kraft pulp that is presently being blended with semichemical stock in the production of corrugating medium. Perhaps it will be possible to fiberize mechanically at least some of the knotter rejects to salvage the yield that is lost as a result of recooking.

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An Electrostatic Process for Applying Dry Coatings on Paper

R. B. REIF

An electrostatic process has been developed for coating paper with dry coating materials in powder form. The coating material, suspended as a dust cloud in air, is charged electrically and deposited on the web with strong electrostatic fields. The general design and operation of the coating unit, the nature and processing of the coating materials, and the types of coatings made by the process are described. Many different resins and pigments can be applied by this process to provide a wide variety of properties in the coatings.

A NEW method has been developed for coating paper with a dry coating applied by means of electrostatic forces. The basic principles of the process have been proved, coating formulations, and methods of processing the coating materials have been developed, and several model coating units have been built and operated successfully. This process was developed for the Bergstrom Paper Co., Neenah, Wis., in work sponsored at Battelle Memorial Institute, Columbus, Ohio. At present, the process has advanced to the pilot-plant stage.

In the Bergstrom process for coating paper, the coating material is applied in the form of finely divided powders. Air rather than water is the vehicle used for transporting the coating materials, and a strong electrostatic field deposits the materials on the paper web. This process is a radical departure from conventional systems and machinery for applying coatings on paper.

THEORY OF ELECTROSTATIC COATING

The principle used in the Bergstrom process for coating paper is basically the same as that used in an electrostatic precipitator. The coating material, suspended as a dust cloud in air, is charged electrically and deposited on the web with strong electrostatic fields.

Charging the air-borne coating powder, an important part of the process, is carried out with unipolar corona discharge. Corona discharge occurs when wires are raised to a high electrical potential. It is visible as a bluish glow in a limited region around the wires. The glow is caused by intense ionization which produces large numbers of ions of both polarities. Ions with opposite polarity of the wire rush to the wire and are neutralized. Ions of the same polarity as the wire are repelled from the wire. Beyond the glow, the ions repelled from the wire form a region of ions of a single polarity. In their travel, many of these ions are captured by coating particles in the air. The polarity of the corona can be changed, so that the coating powder can be charged positively or negatively.

Two particle-charging mechanisms are present in corona discharge; gas ions moving in an electrical field bombard the coating particles, and other gas ions contact the coating particles by ion diffusion. Inasmuch as the coating particles generally are larger than 2 mu in diameter, only the first mechanism is of primary importance in the coating process. Pauthenier (*1*), with the aid of some restricting assumptions, derived an equation for the charge Q on a particle after time t in an electrostatic field of strength E

$$Q = \left[1 + 2\,\frac{(D-1)}{(D+2)}\right]\frac{Ea^2}{e}\left[\frac{\pi NeKt}{1+\pi NeKt}\right]$$

where D is the dielectric constant of the particle of radius a, e is the electronic charge, N is the ion density and K is the ion mobility of the gas. This equation applies primarily to spherical particles, but charging of irregularly shaped particles such as the coating materials is governed by the same factors. High-voltage charging fields obviously are desirable in charging particles. Although the charging of a particle is a function of time, most of the final charge is attained in about 0.01 sec.

In the Bergstrom coating unit, the charging mechanism consists of a series of small wires equally spaced from a large plate electrode. When more than one wire is used, the additional wires suppress the emission of electrical charges somewhat, and the total emission from all of the wires, while greater than that from a single wire, is not proportionately greater than that from a single wire. However, it is sufficient to review the case of the single wire. For a single wire at distance d from a plane surface electrode, the electric field intensity E is given by:

$$E = \frac{V}{r \ln (2d/R)}$$

where V is the applied voltage, R is the radius of the wire, and r is the distance from the center of the wire to any point in the field. To obtain high intensity fields, wires of small diameter, about 0.005-in. are used in the charging unit. These wires are raised to a potential of from 13 to 26 kv.

Charged particles of powder are driven onto the paper by the forces exerted by strong electrostatic fields.

R. B. Reif, Graphic Arts Division, Battelle Memorial Institute, Columbus, Ohio.

The motion of the particles toward the paper is governed by the viscosity, μ, of the air stream, which retards the particles, and the electric force EQ, which accelerates the particles. For spherical particles obeying Stokes' Law, the terminal velocity, v, of a particle is given by:

$$6\pi\mu va = EQ$$

or

$$v = \frac{EQ}{6\pi\mu a}$$

As Q, the charge on the particle, is a function of time, the particle does not attain full velocity immediately; however, the maximum velocity should be reached in about 0.01 sec.

The electrical field between the charging wire and plate electrode drives the coating powder toward the plate electrode where a moving web of paper intercepts the particles that reach the plate. The particles that do not reach the paper here are deposited on the web as it passes through a second electrical field between two large parallel plate electrodes. The field E between the parallel plates is described by the simple equation:

$$E = \frac{V}{d}$$

where d is the distance between the electrodes and V is the applied voltage. To deposit a particle moving in the air stream of velocity a between the two electrodes of length L, the particle must reach the paper in time t where $t = L/a$.

BASIC DESIGN OF COATING UNIT

Figure 1 is a diagram of the Bergstrom electrostatic unit for coating paper. It consists essentially of (1) a closed system for generating and circulating a cloud of coating powder, and (2) a means for electrically charging and depositing the coating powder on the paper web in the coating chamber. The coating powders are fed into the circulation system upstream from the blower. Passing through the blower breaks up agglomerates and suspends the powder in the air stream.

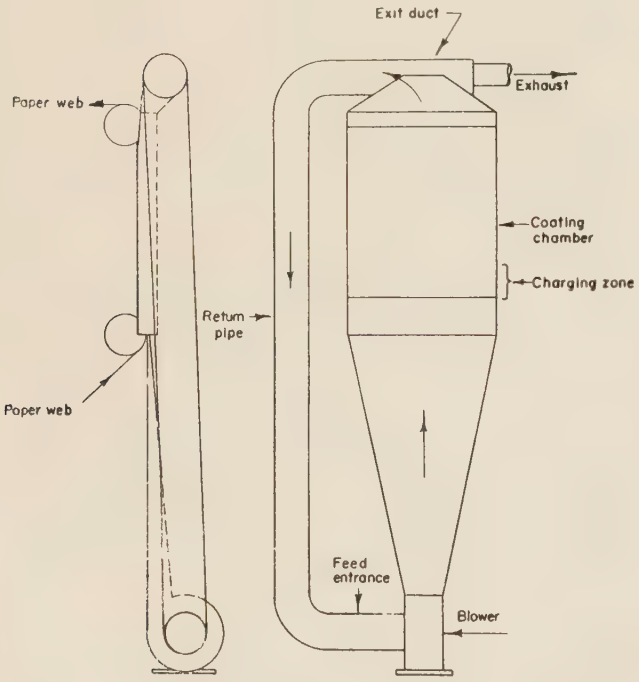

Fig. 1. Diagram of electrostatic coating unit

Figure 2 is a photograph of the coating unit, and Fig. 3 is a diagram of the coating chamber showing the charging wires and electrodes used in depositing the coating on the paper. The paper web passes over the front electrode. Near the entrance of the coating chamber, corona emission produces a region of ionization between the charging wires and the front electrode. The charging unit is usually at the same high potential as the rear electrode. The operating potentials usually are from 13 to 26 kv.

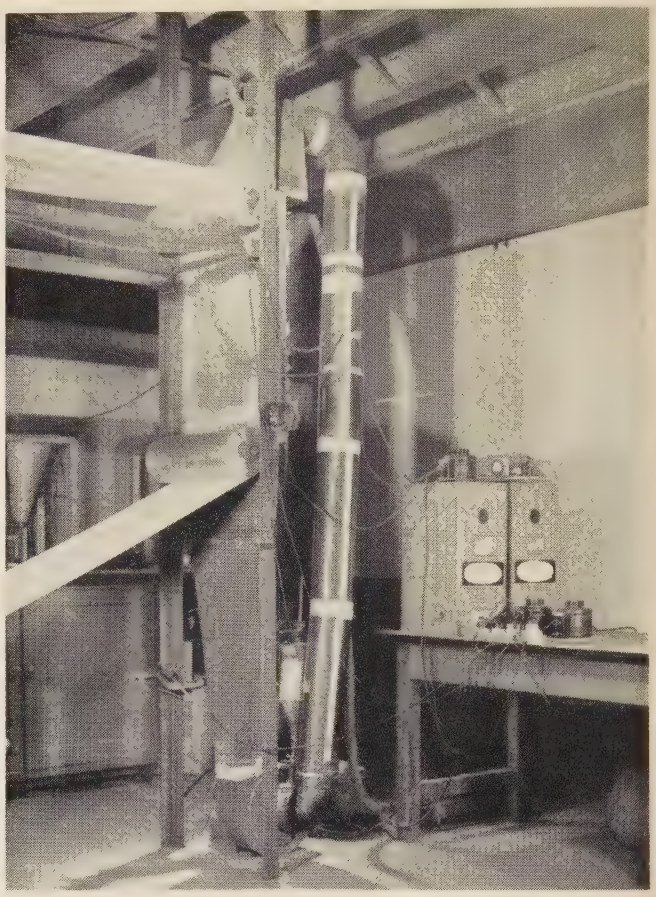

Fig. 2. Electrostatic coating unit

As the air-borne coating powder enters the coating chamber, it passes through a curtain of ions which charges it to one polarity. Part of the powder is deposited immediately, and the rest passes into the electrostatic field between the large parallel electrodes where the electric field drives it against the web of paper. Particles not charged sufficiently to be deposited return to the blower and are recycled.

OPERATION OF COATING UNIT

Coatings from 3 to 20 lb., basis 25 × 38—500, have been deposited on webs moving at rates up to 100 f.p.m. Much faster speeds probably can be attained. Web speed probably will be limited only by the rate at which the electrical charge can leak off the powder deposited on the web. The electrical charges must drain off the coated web before leaving the strong electrostatic field. Otherwise, repulsion of the like charges on the web and

coating powder may cause disturbances in the coating that will mar the appearance of the finished paper.

Once the coating is deposited on the paper and leaves the coating unit, it is fixed to the paper with heat. This

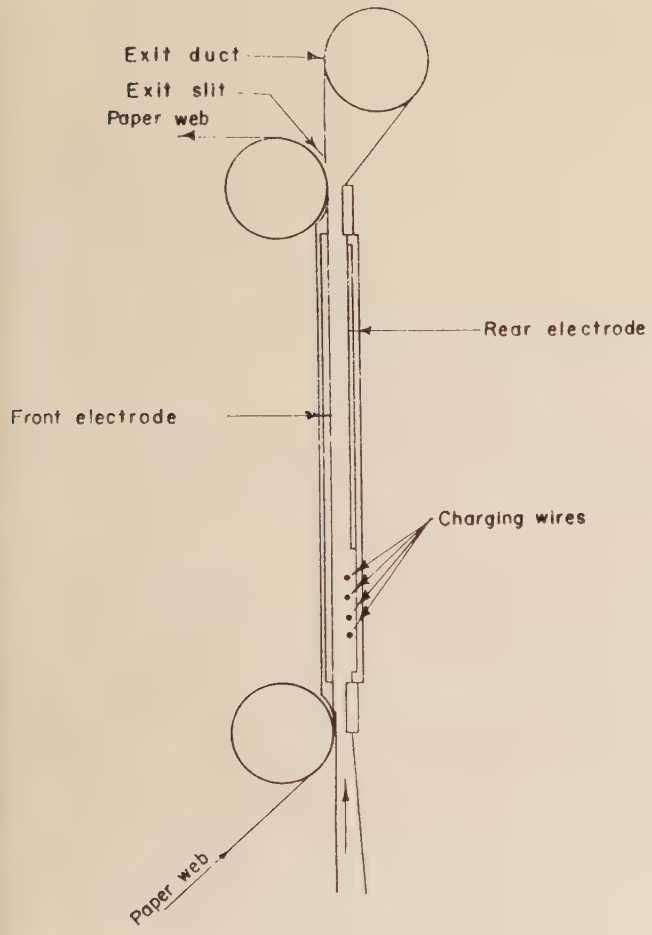

Fig. 3. Schematic diagram of coating chamber

fusing is done as the web passes through an infrared oven or over a heated roll.

NATURE OF COATING MATERIALS

The coating applied by the electrostatic process usually consists of pigments and a heat-sensitive binder. The binder may be thermoplastic (fuses when heated) or thermosetting (hardens after passing through a plastic stage on initial heating). Usually the binder consists of a blend of materials such as film-forming resins, brittle resins, plasticizers, waxes, and other modifying materials. Satisfactory coatings have been made with vinyl copolymers, cellulose derivatives, polyamides, polystyrenes, and many other natural and synthetic resins. Because many different resins are available, a wide variety of properties can be obtained in the coatings.

In the course of the work done at Battelle, over 700 different coating formulations were evaluated. Not only are the dielectric properties of the materials important in controlling the charging and deposition of the coating, but the melting point, adhesive strength, film-forming characteristics, and plasticity of the materials are factors that can be adjusted to obtain satisfactory mechanical properties in the coatings.

PROCESSING OF COATING MATERIALS

Coating materials must be ground before use, preferably to an average size of from 5 to 10 mu to prevent graininess in the coatings. Coatings containing less than 50% pigment can be made from mixtures of finely ground pigments and binder materials. However, for coatings having higher percentages of pigment, the pigment must be blended in the molten binder before it is ground to improve the adhesion of the coating to the base paper and to prevent dusting of the surface of the coating.

To make coatings with more than 50% pigment, the coating materials are blended in a Banbury mill, or a heavy-duty mixer. After the materials are mixed thoroughly and cooled, the mixture is ground into a fine powder. The grinding operation consists of precrushing the lump material with a comminuting machine to reduce the particle size to $^1/_4$-in. or smaller, and then fine grinding in a jet pulverizer. The precrush operation helps to produce a uniform particle size in the final product.

Through use of this blending technique, as much as 80% pigment loading has been obtained in coatings.

TYPES OF COATINGS

Because of the resinous nature of the binder, the coatings usually have the characteristics of plastic coatings; and the high pigment loading also gives some properties similar to the highly pigmented coatings applied in water systems. A wide variety of colored coatings can be made by mixing commercial colored pigments with the binder materials. On the other hand, coatings need not contain pigments. Plastic films can be prepared by this process.

In addition, paper can be coated with mica, flock, and metallic pigment. Carbon paper and waxed paper can be prepared also. Coatings can be applied on one side or on both sides of the web. Heating the coatings gives matte finishes, but the coatings can be supercalendered to bring out gloss and to smooth the surface. A special cast-coating operation was developed also to produce a surface with extra high gloss.

FUTURE OF ELECTROSTATIC COATING

A major advantage of this process is its adaptability to different types of coatings in a variety of colors. In addition, no water or solvents are necessary, and relatively high pigment loading can be obtained in the coatings. Cleanup and maintenance of the coating unit are simple.

Cost estimates have been made for several types of coatings applied by the electrostatic process. On the basis of these estimates, the economics of the process compares favorably with conventional methods. The Bergstrom coating process particularly is suited for small-job work and specialty coatings. The versatility of the process recommends it for producing many of the better-known types of coated papers as well as for making unique coated products in web form.

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A Study of the Lignin Removed During a Neutral Sulphite Cook of Aspen

J. E. STONE

Cooking liquors withdrawn from the digester at various times during a neutral sulphite cook of aspen have been oxidized with alkaline nitrobenzene. The vanillin and syringaldehyde so formed were determined and their ratio found to change continually throughout the cook. The syringaldehyde yield was zero at the start of the cook, but increased until the final liquor yielded twice as much syringaldehyde as vanillin. When calculated as a percentage of the lignin in the liquor (the lignin being determined by ultraviolet spectrophotometry), the yield of vanillin was approximately constant throughout the cook whereas the syringaldehyde yield continually increased.

A RECENT study in these laboratories by Quick (*5*) was concerned with the carbohydrate material removed from aspen (*Populus tremuloides*) at the various stages of a neutral sulphite cook. This study made available a series of liquors taken from the digester at various times during the cook and it appeared of interest to make a brief study of these liquors from the point of view of the lignin present. Of chief concern was the question as to whether pronounced differences could be found between the lignin removed during the early stages of the cook and that removed later.

The question immediately arose of how to isolate the lignin. Quick (*5*) had found that the material precipitated from the liquors with acid represented only a fraction of the lignin as determined by ultraviolet absorption measurements or by subtracting the lignin in the pulp from the lignin in the wood. This is not surprising in view of the fact generally accepted today that some lignin is acid soluble. Rather than risk any separation scheme, therefore, which might fractionate the lignin and yield only one of the fractions, it was decided to use the whole cooking liquor. The characterization of the lignin in the various liquors would be made by carrying out an alkaline nitrobenzene oxidation followed by a determination of the vanillin and syringaldehyde so formed.

EXPERIMENTAL

The cooking conditions used by Quick were similar to commercial practice. The maximum temperature was 171°C. and the yield after a total cooking time of 210 min. was 76.3%. The initial pH was 8.3 and the final pH, 7.05. Liquor was removed from the digester after 30, 60, 90, 120, 150, 180, and 210 min. from start-up, the temperatures at these times being 64, 100, 133, 164, 171, 171, and 170°C.

The oxidation of the liquors and determination of aldehydes was carried out by the micro-method of Stone and Blundell (*6*). The first four liquors—i.e., at 30, 60, 90, and 120 min., were concentrated to about half volume. The others were used (after filtration) just as they came from the digester. One milliliter of liquor was made up to 2 normal in sodium hydroxide by adding 0.5 ml. of 6 *N* NaOH, 0.15 ml. of nitrobenzene was added, and the small bombs containing this mixture heated at 160°C. for 2 hr. with agitation. Aliquots of the liquors were then chromatographed and the vanillin and syringaldehyde determined spectrophotometrically at the appropriate wavelengths. For comparison, an oxidation was also carried out on the original wood (*Populus tremuloides*), ground to a 60–80 mesh meal.

RESULTS

The results are shown in Table I and Fig. 1. The ratio of vanillin to syringaldehyde obtained from the various liquors changes throughout the course of the cook. Both aldehydes increase in amount but syringaldehyde, which could not be detected in the 30-min. liquor, increases much more rapidly than the vanillin, until it predominates by a factor of more than two. Basing the aldehyde yield on the amount of lignin in the liquor (the lignin being determined by ultraviolet absorption measurements), the yield of vanillin is seen to stay approximately constant whereas the yield of syringaldehyde steadily increases.

DISCUSSION

The conclusion cannot be escaped that the lignin removed from the wood at the early stages of the cook is different in composition to that removed later. As the cook progresses the lignin found in the liquor approaches the composition of the total lignin in the wood so far as vanillin and syringaldehyde production is concerned. The reason for the differences between the liquors may be either that there is a different ratio of guaiacyl to syringyl groups actually present or that there is a different ratio of the oxidizable bonds joining these groups to the parent molecule.

The constancy of the vanillin yield when based upon the ultraviolet lignin is remarkable in view of the calculations involved and the very large differences in absolute amount of lignin present in the various liquors—forty-fold in going from the first to the last liquor. The constancy of vanillin yield even extends to an oxidation of the wood meal itself. It seems very unlikely that this situation is fortuitous and based upon compensating errors. The result suggests the existence of a comparatively uniform guaiacyl polymer which appears in the liquor in increasing amounts during the course of the cook, giving a certain absorption in the ultraviolet, and which is oxidizable to a definite yield of vanillin regardless of the amount present. It may be that the absorbance of ultraviolet light at 280 mmu, used in the

J. E. STONE, Research Assistant, The Institute of Paper Chemistry, Appleton, Wis.

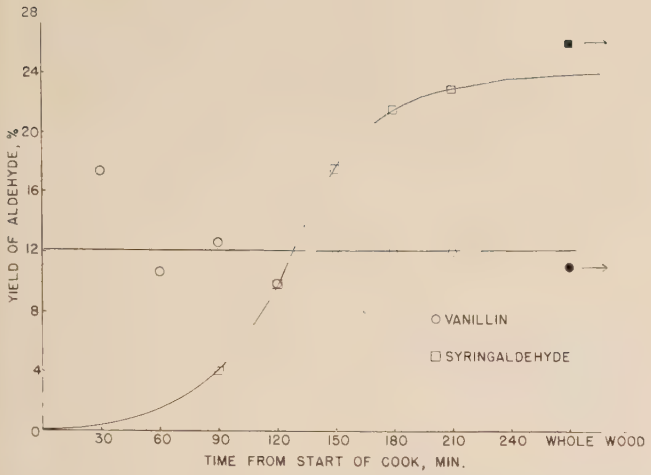

Fig. 1. Aldehyde yield from alkaline nitrobenzene oxidation of liquors from neutral sulphite cook of aspen

determination of "lignin," is due to the presence of the same groups and bonds which are susceptible to oxidation. A constant ratio of "lignin" to vanillin would therefore not be surprising because they would be two different ways of measuring the same thing. This hypothesis is greatly complicated by the amounts of syringaldehyde formed. The syringaldehyde yield, based on the ultraviolet lignin, increases from zero to 23.0% of the lignin in the course of the cook, suggesting that the polymer containing syringyl groups is less soluble than that containing guaiacyl groups, either because of structural differences or a different location in the cell wall, and therefore does not appear in the liquor until much later in the cook. Alternatively, the "syringyl lignin" does appear in the liquor at the start of the cook but contains no bonds capable of being oxidized to an aldehyde group. This will be discussed later. If it is the syringyl groups which are absent in the early stages of the cook, it appears to follow that the "syringyl lignin" does not contribute to the ultraviolet absorption. If it did, the yield of vanillin should decrease as more and more syringyl lignin appeared in solution. Furthermore, if the ultraviolet absorption of the lignin represents both guaiacyl and syringyl groups, then the sum of the two aldehyde yields rather than just one of them should be proportional to the lignin content. The data show quite clearly however that the sum of the two aldehydes bears no simple relationship to the ultraviolet lignin in the liquor. The question arises as to the validity of basing calculations on a lignin content obtained solely from ultraviolet measurements. There is naturally some doubt about values obtained in this way but no better alternative presents itself. At four times during the cook, pulps were obtained which permitted a Klason lignin determination, and through a knowledge of the lignin content of the original wood and the liquor-to-wood ratio, it is possible to calculate the amount of lignin lost from the wood and entering the liquor at any stage of the cook. These values are given in Table I. They, too, depend on an ultraviolet measurement, however, for the acid-soluble lignin obtained during the Klason lignin analysis is determined spectrophotometrically and represents a considerable portion of the total lignin. This method of calculating lignin cannot therefore be considered superior to the ultraviolet measurement on the cooking liquor itself. In any case, the use of a "lignin by difference" value for the lignin in the cooking liquor does not make the lignin in the liquor proportional to the amount of vanillin and syringaldehyde obtained from the liquor. Although a number of hypotheses might be advanced to explain the nonequivalence of ultraviolet lignin (or any other lignin) and aldehyde yield, there is really insufficient evidence at present to warrant too much speculation.

Returning now to the question of the changing ratio of vanillin to syringaldehyde during the course of the cook, it was previously suggested that this could be due to either a change in the number of syringyl groups actually present or only to a change in the number of oxidizable bonds joining the syringyl groups to the parent molecule. A methoxyl determination should settle this question if the lignin could be freed from methylated carbohydrates. It seems likely that an absence of syringyl groups rather than oxidizable bonds is responsible for the low syringaldehyde yield from the early liquors. Kudzin and Nord (*3*) found that the native lignin from oak, birch, and maple—i.e., the more soluble lignin which might be expected to appear in a cooking liquor at an early stage of the cook—gave a much lower syringaldehyde yield (nil in the case of oak and birch) and had a lower methoxyl than the total lignin from the whole wood. The lower methoxyl suggests a reduction in the number of syringyl groups present. Lovell and Hibbert (*4*) obtained a native lignin from aspen and separated it into three fractions with methoxyl contents of 16.0, 17.7, and 18.4%, all of which are lower than the methoxyl content of Klason lignin obtained from the wood. This again suggests a lower syringyl content in the more soluble lignin fraction. Buchanan, Brauns, and Leaf (*2*) obtained a "crude" aspen native lignin with a methoxyl content of 17.6% which, when purified, had 19.5% methoxyl.

Table I. Yield of Vanillin and Syringaldehyde from Liquors Obtained During Neutral Sulphite Cook of Aspen

Time from start of cook, min.	*Lignin in liquor, g./100 ml.*		*Vanillin, g./100 ml.*	*Syringaldehyde, g./100 ml.*	*Aldehyde yield, %*				*Ratio of vanillin/ syringaldehyde*
					Based on ultraviolet lignin		*Based on lignin by difference*[a]		
	By ultraviolet	*By difference*[a]			*Vanillin*	*Syringaldehyde*	*Vanillin*	*Syringaldehyde*	
30	0.052	0.025	0.009	Not detectable	17.4	...	36.0	...	...
60	0.112	...	0.012	Not measurable	10.6	...	...	...	...
90	0.284	0.500	0.036	0.012	12.6	4.2	7.2	2.4	3:1
120	0.763	...	0.075	0.075	9.8	9.8	...	...	1:1
150	1.15	1.55	0.141	0.202	12.2	17.6	9.1	13.0	1:1.4
180	1.47	...	0.177	0.316	12.0	21.6	...	...	1:1.8
210	2.20	2.28	0.264	0.504	12.0	23.0	11.6	22.0	1:1.9
Wood-meal, 46.5 mg.	...	9.86 mg.[b]	1.08 mg.	2.56 mg.		Vanillin: Syringaldehyde	11.0[b] 26.0	...	1:2.4

[a] Lignin in wood minus lignin in pulp, each lignin being the sum of Klason plus acid-soluble lignin. Quick (*5*).
[b] Based on sum of Klason plus acid-soluble lignin in wood.

This "purification" consists in part of precipitation from alcohol by water, and this procedure necessarily eliminates the water-soluble fraction which is therefore quite possibly lower in syringyl groups than the water-insoluble material since its removal raises the methoxyl content of the remainder. It is likely to be the water-soluble lignin which is removed during the early stages of a cook. Aaltio and Roschier (*1*) obtained a series of lignins from a butanol-water cook of aspen (*Populus tremula*) buffered around pH 6 to 7, and found that the methoxyl content steadily decreased with increasing lignin removal. This appears to be in direct conflict with the present findings. However, their first cook removed over 40% of the lignin with the rest of the series of lignins being obtained during the removal of the remaining 60%. In the present work the lignin studied was that from zero to 40% removal.

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Some Aspects of Dispersion

W. R. WILLETS AND L. E. GEORGEVITS

The proper dispersion of pigments in a coating color is of the greatest importance. Even if occasional particle aggregates are not so large as to cause "sandy coatings," which would obviously be detrimental to good printing, inefficient dispersion even at a much lower size level will detract from the basic covering power and brightness characteristics of any pigment. It is a well known fact that the optimum value of colored pigments is only developed by their maximum dispersion (whether in paints, inks, or paper coatings) and it is equally true that the optimum value of white pigments is similarly dependent on their proper dispersion.

No attempt will be made in the following discussion to go into the various theories of dispersion which have been well covered in many technical books and articles appearing in scientific periodicals. However an attempt will be made to note and illustrate some of the simpler and more practical aspects of dispersion and the possible effect on the final coating.

BASIC CONCEPTS

A dispersion of a pigment in a coating color may be defined most simply as the uniform distribution of the pigment solid particles in the liquid vehicle. The powdered pigment consists of aggregations of smaller particles. Mechanical work is required to disperse the pigment in the vehicle, and the forces so imposed on the aggregates cause them to break down into smaller units. Once so dispersed the particles are free to move about and to form different associations than existed in the original aggregates. They may be kept in the dispersed condition, or flocculated by the addition of materials which will alter the charges on them.

A primary particle (Fig. 1) is usually considered as one which can only be reduced in size through fracture. Generally, such primary particles are more of theoretical than of practical interest since it is questionable whether many grinding or milling procedures reduce the powdered pigment to this extent. The actual particle dealt with, sometimes known as the "ultimate working unit," is usually a group of primary particles that retains its structure throughout the dispersion process, and is commonly called an aggregate.

Aggregates vary in their properties. A dense aggregate (Fig. 2) is composed of primary particles so closely bound together that it can be considered as a large primary particle while an open structure aggregate has the primary particles closely bound yet spaced far enough apart to give an open structure (as shown in Figs. 3 and 4). An agglomerate may be considered as a loosely bound, soft aggregate frequently formed by the dry handling of the pigment containing some adsorbed air. A large aggregate in a field otherwise essentially composed of primary particles is shown in Fig. 5. A flocculate can be considered as a loose cluster of primary working units which were in the dispersed form prior to flocculation, and this condition is shown in Fig. 6 which depicts a dispersion before and after flocculation.

All these must be considered in the preparation of coating colors. Large pigment aggregates or flocculates in the final color can result in poor finish and picking. Since the optimum particle size to develop maximum covering power and brightness is in the range of half the wavelength of light, oversize aggregates or flocculated pigment adversely affect pigment efficiency. The effect of particle size on the hiding power of a rutile titanium pigment is shown in Fig. 7. These points are all of particular interest as regards titanium pigments since the size of the ultimate working unit, if properly developed, is in the ideal range for optimum opacity and brightening power. Titanium pigments have greatly improved in their dispersion characteristics as shown by the comparisons illustrated in Fig. 8, typical routine dispersion tests.

Generally, in the paper industry a good dispersion means that the pigment is finely divided—that is to say free of any large aggregates. It is, of course, possible to have finely divided ultimate working units in a flocculated system but usually a good dispersion refers to a deflocculated system. Thus, a good dispersion can be considered as the result of the reduction in size of the aggregates by mechanical means together with the presence of a deflocculating, surface active material known as a dispersant or a dispersing agent.

W. R. Willets and L. E. Georgevits (now with the Borden Co., Chemical Div.) Technical Service Laboratories, Titanium Pigment Corp., New York, N. Y.

Table I. Effect of Alkali on Dispersing of Pigments in Water

	Total solids, %	NaOH based on pigment, %	pH	Viscosity, sec. No. 4 Ford cup	
				As made	After 24 hr.
Coating clay	59	0.1	7.7	60	Puffy
	59	0.15	8.3	30	30
Anatase—water dispersible type titanium dioxide	75	0	6.9	16	Puffy
	75	0.03	7.7	22	Puffy
	75	0.06	..	Paste	..
Anatase—medium oil type titanium dioxide	43	0	..	Puffy	..
	43	0.13	10.9	19	19
	46	0.15	11.1	26	16
Rutile—nonchalking type titanium dioxide	70	0.06	9.1	12	19
	75	0.09	9.3	17	27

DISPERSANTS

The selection of a dispersing agent is frequently an important matter. For example, a small amount of alkali makes it possible to prepare a fairly high total solids water slurry of clay and of some types of rutile titanium dioxide, but is ineffective with a water-dispersible grade of anatase titanium dioxide and only slightly effective with a "medium oil" type of anatase titanium dioxide, as shown in Table I. It must be borne in mind that these results are only illustrative and that clays and pigments from different sources might behave quite differently. However the data do show that as simple a surface active agent as caustic soda is very effective in dispersing at least one type of rutile titanium dioxide, fairly effective in dispersing one type of clay, slightly effective in dispersing one type of "medium oil" titanium dioxide, and actually of negative value in dispersing one type of water dispersible titanium dioxide.

In preparing water slurries of clays such materials as sodium silicate have also been used but these have not been found particularly suitable for other pigments, especially where high total solids water slurries are required. Probably the most important dispersing agents are the glassy sodium polyphosphates, such as sodium hexametaphosphate, tetrasodium pyrophosphate, and sodium tetra phosphate and many others sold under various trade names. Certain pigments such as the "water dispersible types" of titanium dioxide or "predispersed" clays have soluble salts absorbed on the pigment particles which act similarly to the use of an added dispersant. For example, a water-dispersible titanium dioxide can be made into a water slurry of 75% total solids, and occasionally higher providing distilled or soft water is used. If hard water is used the occluded soluble salt must first act to sequester calcium and magnesium ions before exerting its dispersing action. Similarly, if nonwater dispersible grades of pigment are used together with a glassy phosphate as a dispersant, it is possible to make high total solid slurries, but the amount of dispersant required will be much greater if the water is hard than if it is soft.

However, it should be emphasized again as it has been many times in the past that the use of too much of such a dispersant reduces its efficacy, and that more may be required for one pigment than for another. It is well to determine by titration or a few other preliminary laboratory tests the dispersant requirement of a pigment using the same water that will be used in commercial operation. When using a glassy phosphate dispersant, pH may play an important role in some cases, much less in others, as shown by the data of Table II. These data which again are given only by way of illustration still serve to indicate that it is always advisable to determine beforehand the optimum conditions for dispersing a given pigment as a water slurry, and not to assume that the optimum conditions for one pigment will necessarily be the best for another.

Many simple methods for determining the dispersant requirement of a pigment will be apparent to the technician. One of the simplest merely involves setting up a water slurry on a high speed laboratory mixer and adding small increments of the dispersant, determining the viscosity at each increment. The minimum viscosity will indicate the best dispersion and therefore the correct amount of dispersant to use. Actually, in practice a slight excess is almost always desirable since a bit too much is better than a bit too little.

Organic dispersing agents have been frequently suggested and some of these have proven very effective in

Table II. Effect of Sodium Hexametaphosphate on Dispersion of Pigments in Water at Varying pH

	Total solids, %	Per cent based on pigment		pH	Viscosity, sec., No. 4 Ford cup	
		NaOH	Sodium hexameta-phosphate		As made	After 24 hr.
Coating clay	70	0	0.3	5.3	65	60
	70	0.1	0.3	7.0	30	30
	70	0.2	0.3	9.7	23	23
Anatase—water dispersible type titanium dioxide	75	0	0	6.9	16	Puffy
	75	0	0.1	7.0	16	Puffy
	75	0	0.2	7.2	40	Puffy
Anatase—medium oil type titanium dioxide	70	0	0.4	7.5	14	16
	70	0.03	0.4	9.2	21	22
	70	0.06	0.4	9.7	22	22
Rutile—nonchalking type titanium dioxide	75	0	0.4	8.2	13	13
	75	0.06	0.4	8.7	13	13
	75	0.12	0.4	9.7	13	13

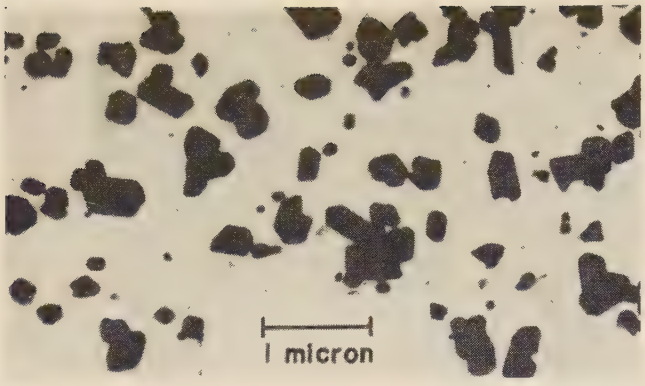


Fig. 1. Primary particles of titanium dioxide electron micrograph; × 14,000

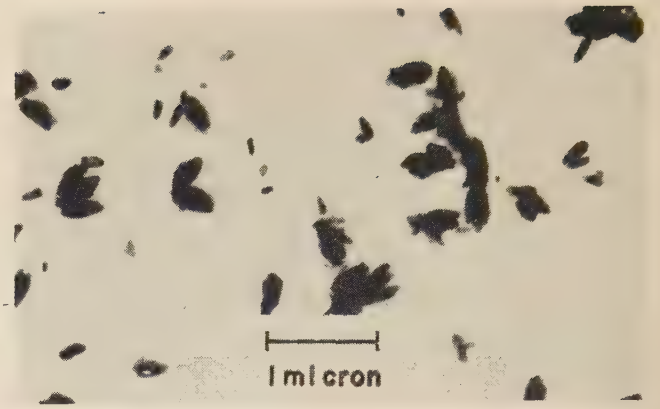


Fig. 3. Open structure aggregates of titanium dioxide electron micrograph; × 14,000

other fields. A common one is gum arabic which is an effective dispersing agent for "paint grades" of titanium pigments and similar materials. However, some years ago it was noted that when a fluid dispersion of titanium-calcium composite pigment was made at 65% total solids by using 2% gum arabic (based on the pigment) and this was mixed with a fluid slurry of clay prepared at the same total solids using a polyphosphate, the mix flocculated badly although this was not evident at lower solids of 50% or less. Similarly, when gum arabic was added to a high total solids slurry of a water dispersible titanium dioxide, the slurry thickened and flocculated. These instances demonstrated that care should be taken in using surface active agents, dispersants, and the like, to make sure they are compatible with each other and with the pigments with which they are used.

This can be illustrated by a few simple tests noted in Table III in which slurries of 66.7% solids were prepared of clay and of a medium oil-type anatase titanium dioxide, using a glassy polyphosphate in one instance and gum arabic in the other. In the case of both pigments the glassy polyphosphate proved the more effective dispersant although gum arabic also gave fluid slurries. When the clay and titanium dioxide slurries prepared with the glassy phosphate were mixed, the final viscosity was in between that of each, when the slurries prepared with gum arabic were mixed the final viscosity was higher than that of either of the separate slurries and when the clay slurry prepared with the polyphosphate was mixed with the titanium dioxide slurry prepared with the gum arabic, the final viscosity was much higher than that of either taken separately.

Here again the examples given are only indicative of what may happen and not conclusive of what will happen. Different types of pigments and clays may behave differently than the examples given, such factors as total solids and pH may well have an effect and, in general, what is found to hold in one case may or may not hold in another. However, it is always well to determine the effect of any dispersant at the conditions under which it is to be used rather than to assume a specific behavior.

Alkali-cut casein or alpha protein have also been widely used for dispersing pigments especially if they are to constitute the final binder in the vehicle, or if a latex is used in which case they exert a stabilizing effect on the latex emulsion. Generally speaking, about 3% of the casein or protein, based on the pigment, is used and is incorporated directly in the slurry water. The total solids attainable are less than those resulting from the use of optimum amounts of glassy polyphosphates and there is naturally a greater tendency to foam.

Volumes have been written on dispersion and the effect of surface active agents. While the above discussion has deliberately avoided the many complexities involved it has attempted to illustrate that the proper selection and use of a dispersing agent in the preparation of water slurries for incorporation into coating colors is important and not quite as simple as frequently assumed.

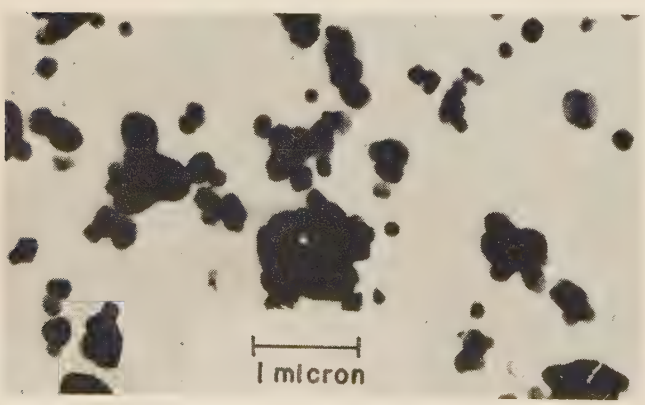


Fig. 2. Dense aggregates of titanium dioxide electron micrograph; × 14,000

Fig. 4. Open structure aggregates of titanium dioxide electron micrograph; × 14,000

FLOCCULATION

It was noted earlier that a pigment could be completely dispersed and then flocculated or agglomerated by subsequent treatment. This has been observed in a number of instances where a casein or isolated protein solution was added very quickly to a thoroughly dispersed slurry of a titanium pigment or clay or of a mixture of both. This condition has been known as "casein shock" or "protein shock." If the adhesive solution is added very slowly with thorough mixing, or if a small amount of it is used when the pigment slurry is milled, such flocculation is minimized. Actually, the agglomerates so formed are usually very loose and soft and would break down under continued agitation but there may be cases where a coating is used soon after preparation where the flocculates might persist and show up as lumps in the final coated sheet.

Fig. 5. Large aggregate in a field otherwise essentially composed of primary particles; × 8900

This type of "shock" is shown in Fig. 9. The slurries were milled so as to be virtually aggregate-free and then alkali-cut casein added very rapidly causing aglomeration ("shock") in one case and also very slowly with constant mixing, in which case virtually no agglomeration occurred. The various mixes were drawn down on glass slides and photographed at about 13 diameters using a grazing light at an angle of 8° and a Polaroid camera set-up (Fig. 10).

Here again the above is illustrative of what may happen. Flocculation can definitely occur under other conditions, and the above is cited merely by way of illustration.

Table III. Effect of Sodium Hexametaphosphate and Gum Arabic as Dispersants

Pigment	Dispersant—Kind	Dispersant—Per cent based on pigment	pH	Viscosity, cp. (Brookfield 100 r.p.m.)
(1) Clay	Phosphate	0.5	9.8	226
(2) Clay	Gum arabic	2.0	9.7	1000
(3) Anatase—med. oil titanium dioxide	Phosphate	0.5	8.2	300
(4) Anatase—med. oil titanium dioxide	Gum arabic	2.0	9.4	835
Combinations—50–50 of Above				
(1) Clay	Phosphate	0.5	8.7	236
(3) Anatase—med. oil titanium dioxide	Phosphate	0.5		
(1) Clay	Phosphate	0.5	9.7	6950
(4) Anatase—med. oil titanium dioxide	Gum arabic	2.0		
(2) Clay	Gum arabic	2.0	9.6	1500
(4) Anatase—med. oil titanium dioxide	Gum arabic	2.0		

One rather frequent cause of flocculation in a coating color may be the leaching of alum from the sheet during the coating process where excess coating is returned to the system, as is the case, for example, in size press coating. As the alum leached from the paper builds up in the coating color the pH is lowered and there is apt to be a definite flocculating effect. This can frequently be controlled by maintaining the proper pH in the color by addition of ammonia or other alkali.

Coatings containing synthetic latices in the vehicle may also undergo flocculation and agglomeration if the latex emulsion is broken because of its mechanical or temperature instability.

Generally speaking, once a pigment is properly dispersed in a coating color means should be taken to assure that it is not subsequently flocculated. There may be occasions where a flocculated coating is desirable but these would be the exception rather than the rule.

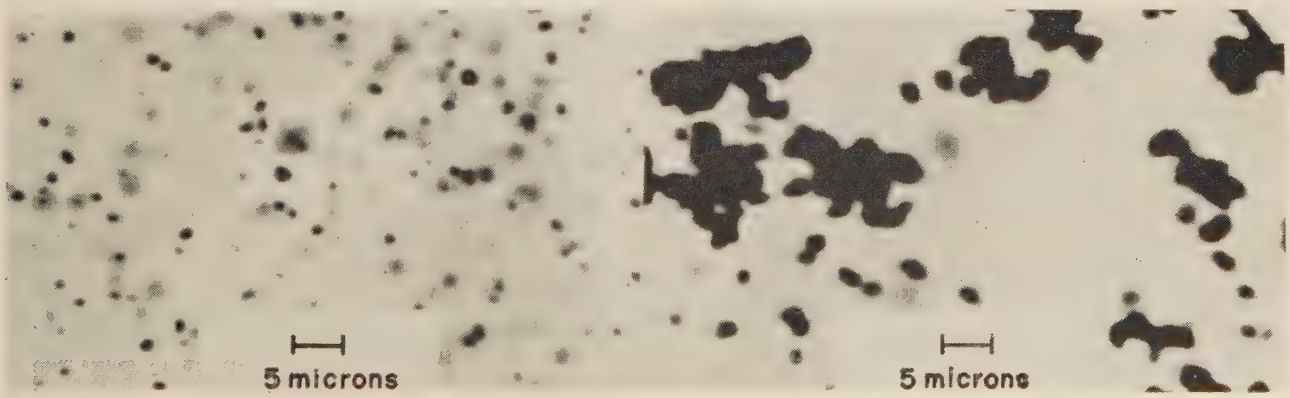


Fig. 6. Photomicrographs of dispersed pigment on left and flocculated pigment on right; × 1350

MILLING

As noted earlier mechanical work is required to break down pigment aggregates into smaller sizes which ideally should be of the order to develop the optimum hiding power. However, this ideal situation is probably rarely obtained and the reduction is to "ultimate working

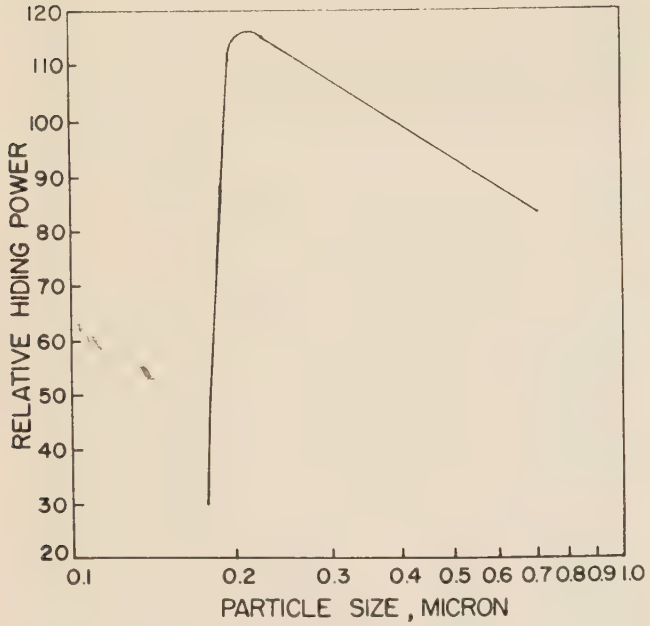


Fig. 7. Relationship between particle size and hiding power for rutile titanium dioxide pigment

units" in a size range that persists throughout the dispersion process.

It is obvious that if large, undispersed aggregates persist and if they are sufficiently large to give an uneven "sandy" finish after coating and calendering, the effect on printing will be bad. This is shown in Fig. 11, representing surface photographs of commercially coated paperboards (made with the Polaroid camera setup) showing a fairly "sandy" coating before and after calendering. While supercalendering has helped to reduce the large "grains" which are so apparent in the uncalendered sheet they are still somewhat evident

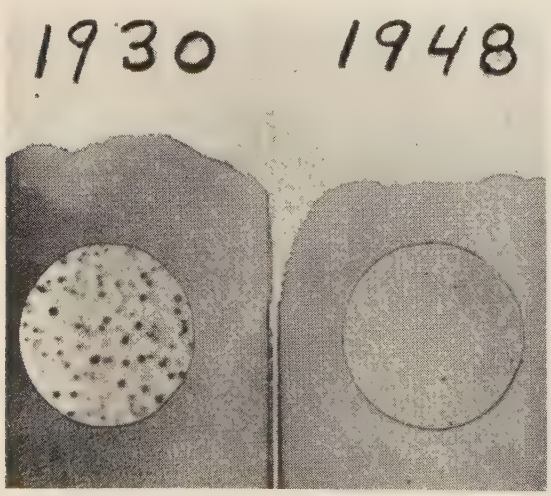


Fig. 8. Improvement in dispersion of titanium dioxide pigment; vintage 1930 versus 1948

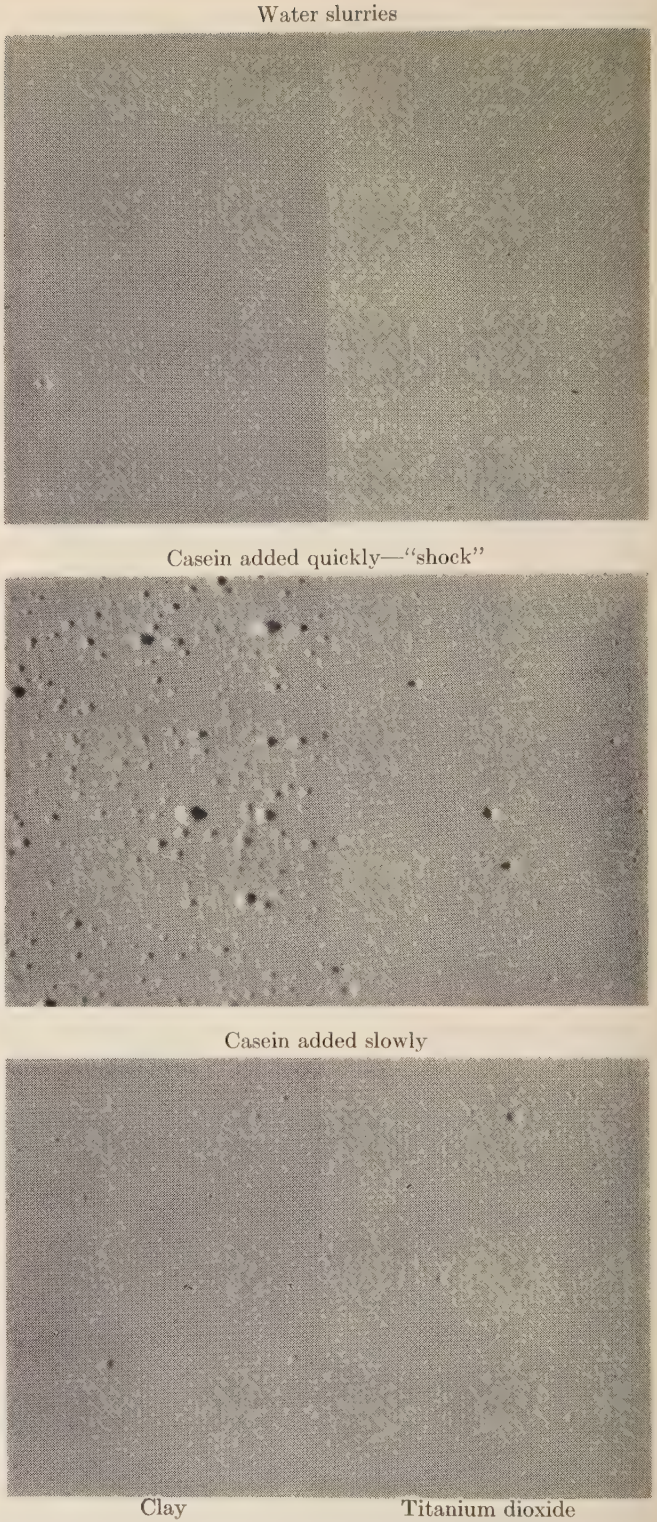


Fig. 9. Effect of speed of adding casein adhesive on flocculation of pigment water slurries

afterwards. An illustration of the effect of milling was obtained when paper was coated with unmilled and milled colors and then printed on a proof press with an over-all black print with the letters remaining uninked in white as shown in Fig. 12. The "sandiness" of the coating in the one case as contrasted with the relative smoothness in the other is evident. While it does not show up very well in the photograph the "sandy" coating picked badly.

In tests on commercial paperboards a color was ap-

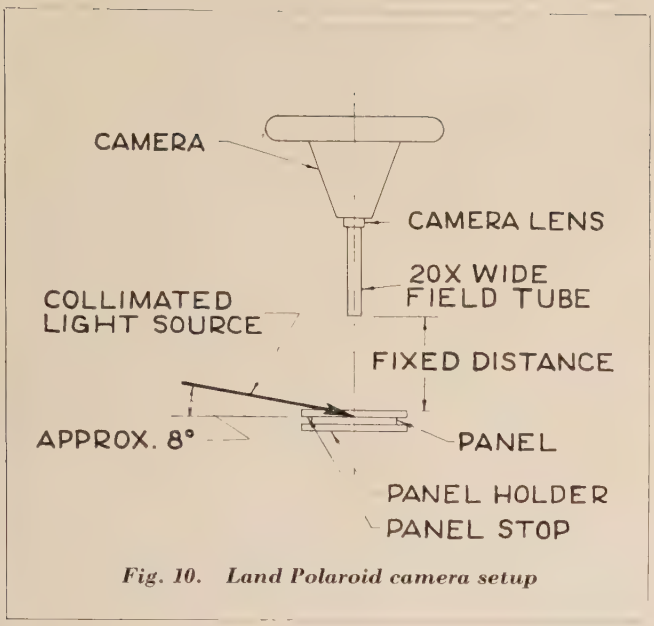
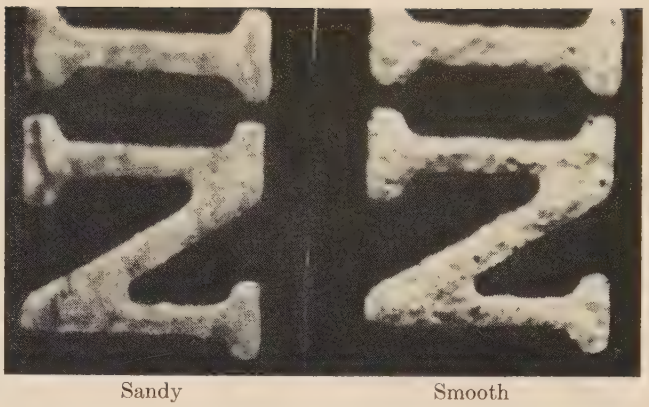


Fig. 10. Land Polaroid camera setup

plied in which the clay-anatase titanium dioxide had been poorly milled prior to adding the adhesive and the result was a very uneven "sandy" coating. In another case in which a rutile titanium dioxide pigment was used the pigment slurry was carefully milled by the use of a high speed stone mill (Morehouse Speedline mill) and the coating thus prepared gave a smooth finish virtually free of any aggregates. In still another case an anatase titanium dioxide-clay color was prepared by heavy duty, high shear mixing directly in the vehicle in dough mixing equipment and then diluted with water by agitation in a storage tank, but here again the coating was rather "sandy." (These surfaces are shown in Fig. 13, taken by the Polaroid camera technique referred to previously.) They serve to illustrate the importance of sufficient mechanical work on pigment aggregates to avoid "sandiness."

In milling high solids content water slurries of pigments on high speed stone mill or colloid mill types of equipment it is well to bear in mind that they may be dilatant in rheological behavior. Instances have been observed where what was apparently a perfectly fluid slurry "froze" when passed through a colloid-type mill because the shearing forces exerted increased the consistency of the slurry to such an extent that it would



Sandy Smooth

Fig. 12. Proof press prints on uncalendered experimental coatings (Polaroid photos)

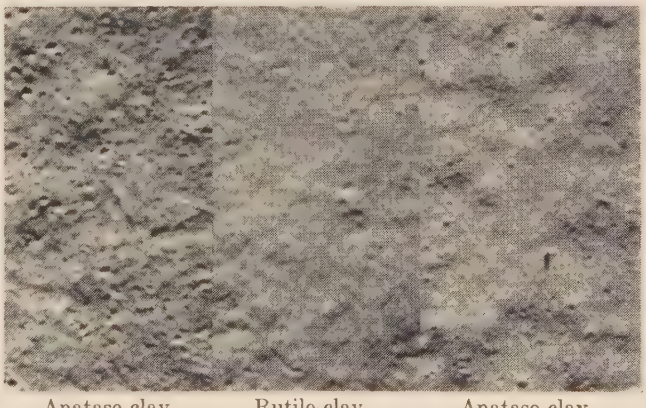
not pass between the stator and rotor surfaces of the mill when in motion. When the power was shut off and the mill stopped the dilatant slurries ran through readily. While it is true that milling is generally most effective when the total solids are high it is equally true that when they are so high that the slurry is dilatant the mill may be rendered inoperative. Whether similar phenomena may occur in heavy duty high shear mixing directly in the vehicle using a dough mixer has not been observed although it does seem possible.

Even though milling may be efficient and achieve the desired degree of reduction in aggregate size there is still the possibility that pigment colors may dry on tank surfaces and on stirrer shafts and fall back into the color where they may fail to disintegrate completely and show up in the final coating as large aggregates or specks. Not all the causes of "sandy" coatings can be attributed to faulty dispersion or flocculation of the pigments.

Even if a coating has been milled so as to reduce aggregates below the level where they may cause a "sandy" coating, additional milling may contribute to the properties of the coating. This was shown in an example where a mixture of 60 parts of clay and 40 parts of a water-dispersible anatase titanium dioxide were mixed under high shear conditions directly in a starch vehicle using a Baker-Perkins mixer. The batch was then diluted and divided with one portion being used for coating after dilution without further treatment and the other passed through a high speed stone mill.

Before calendering After calendering

Fig. 11. "Sandy" coating before and after calendering (Polaroid photos)



Anatase-clay, poorly milled | Rutile-clay, speedline milled | Anatase-clay, high shear mixed

Fig. 13. Effect of milling on coatings (Polaroid photos)

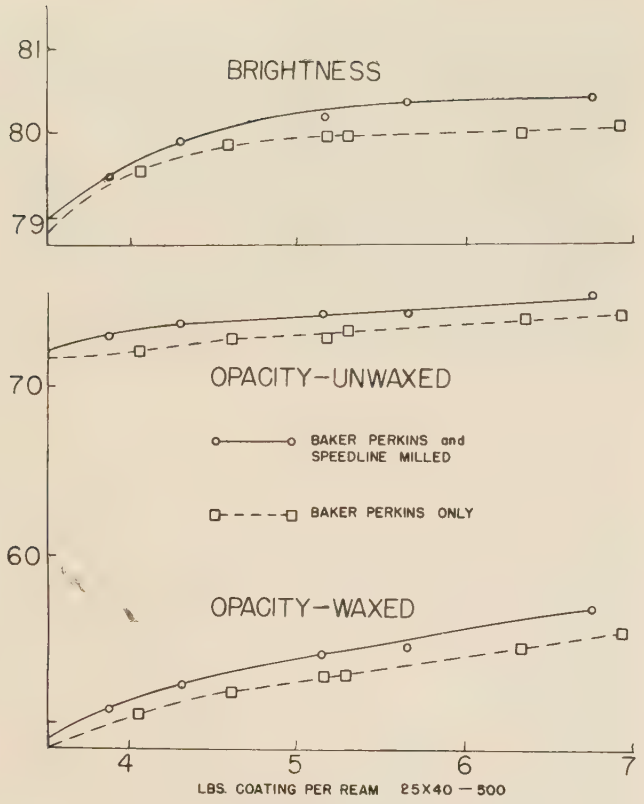


Fig. 14. Effect of milling on opacity and brightness

Various weights of coating were applied to one side of waxing stock using a laboratory coating machine operating on the doctor rod principle. After coating sample sheets were cut, the amount of coating applied accurately determined, brightness and color readings measured and the opacity before and after complete impregnation with wax measured. As a result it was possible to obtain curves showing the effect of the additional milling which demonstrate very clearly that it resulted in better opacity and better color and brightness (Fig. 14).

CONCLUSION

A dispersion of pigments in a coating color is the uniform distribution of the ultimate working units in the liquid vehicle. Such a proper dispersion is the result of the reduction in size of the aggregates to the optimum size range of ultimate working particles. This is accomplished by means of mechanical work ("milling" or "grinding") in the presence of a surface active, deflocculating material generally called a dispersant. Once the pigments are so dispersed care should be taken to prevent reflocculation or agglomeration. Large size aggregates in a coating color may result in uneven finish, rough surface, poor calendering, and "sandy" coatings which cause poor printing and "picking," and in general are undesirable from all points of view.

The optimum ultimate working unit size to develop maximum opacity is in the order of half the wavelength of light. The fact that milling may aid in developing this is shown by the better opacity and brightness developed by milled coatings as against unmilled coatings.

Various dispersants behave differently with different pigments and the proper amounts to be used and the optimum pH should be determined for any given case using the same water and other conditions that will be used in commercial operations. Even though a pigment has been well-dispersed originally it may be flocculated with deleterious effects because of too rapid addition of an alkali-cut casein or isolated protein, mechanical or temperature instability of a latex, leaching of alum from the sheet being coated, and various other factors.

Laboratory tests confirmed by actual mill operations indicate the difficulty of generalizing as regards optimum amounts and types of dispersants and methods of milling. Ideally these should be determined for each specific case.

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Analysis of Tupelo Woods

LOUIS E. WISE and JOSEPHINE PICKARD

Interest in the "gums" or tupelo woods has increased during the past years, because of their importance to the Southern pulp and paper and dissolving pulp industries. In the present study, representative samples of heartwood and sapwood of two species, *Nyssa sylvatica* Marsh (often termed black tupelo or black gum) and *Nyssa aquatica* L. (also known as water tupelo or tupelo gum), were subjected to summative analyses. Hitherto, no such analyses have been recorded.

An early analysis of *Nyssa sylvatica* is given in the literature (*1*). This sample contained 28.6% lignin. Several partial analyses of swamp tupelo [*Nyssa sylvatica*, var. *biflora* (Walt.) Sarg.] have also been made. G. H. Chidester (*2*) analyzed the wood of a shipment of swamp tupelo, *Nyssa sylvatica*, var. *biflora* (Walt.) Sarg. and found 29.0% lignin, 44% alpha-cellulose (the latter presumably isolated from the 54.3% Cross and Bevan cellulose). Chidester also gave data on the solubility of the wood in 1% NaOH, hot water, alcohol-benzene, and ether. Two other analyses of swamp tupelo are listed in an unpublished summary from the Forest Products Laboratory (*3*), which also included Chidester's analyses. None of the analytical data are complete, and only in two cases were total pentosans determined (18.9 and 18.5%). The lignins reported were 26.7 and 29.5%.

E. R. Schafer and Matti Santaholma (*4*) made a series of interesting chemical analyses on various screen fractions of *mechanical pulps* prepared from two samples of swamp tupelo. The analytical data fluctuated

Louis E. Wise, Research Associate, and Josephine Pickard, Technical Assistant, The Institute of Paper Chemistry, Appleton, Wis.

widely with the individual fractions. Analyses of the entire pulp showed that the over-all lignin contents were 26.5 and 28.1%. No analyses of the original wood were given. Unpublished lignin analyses on the extractive-free heartwood and sapwood of a swamp tupelo, made in 1953 at The Institute of Paper Chemistry, were, respectively, 28.7 and 27.0%.

To the best of our knowledge, no analyses of water tupelo have appeared in the literature, but an analysis (made on a sample of extractive-free wood) at The Institute of Paper Chemistry in 1953 showed 25.8% lignin. It is evident from these few scattered analyses that the lignin content of Nyssa species is quite high. Apparently no summative analyses of either *Nyssa sylvatica* or *N. aquatica* have been made in the past.

EXPERIMENTAL

Logs were obtained through the courtesy of the following companies to whom thanks are due: Riegel Carolina Corp. (Bolton, N. C.), Union Bag & Paper Corp. (Savannah, Ga.), Brunswick Pulp & Paper Co. (Brunswick, Ga.), Crossett Lumber Co. (Crossett, Ark.), Gaylord Container Corp. (Bogalusa, La.), Coosa River Newsprint Co. (Centreville, Ala.), and West Virginia Pulp & Paper Co. (Luke, Md.).

In the case of each log the sapwood and heartwood were separated and reduced to sawdust and equal amounts of each type of sawdust were then combined and analyzed. Composite samples of *Nyssa sylvatica* were prepared from six bolts. Those from *Nyssa aquatica* were obtained from five different logs. Thus, the results shown in Tables I and II are fairly representative of the sapwood and heartwood of either species. The techniques used in these analyses have been described previously (*5*, *6*).

The low summative analyses of water tupelo may be contingent on the difficulty of removing all extraneous materials from the wood by neutral solvents.

On the extractive-free basis, the Klason lignin contents of all four wood samples are higher than are those of most of our native hardwoods. Inasmuch as the methoxyl content of any of these lignins is well above 22%, it is not surprising that the methoxyl content of the extractive-free tupelo woods is also exceptionally high. This is above 7.50% and well beyond the range of any of our other common hardwoods. Actually it tops the methoxyl value of nearly all the tropical angiosperms analyzed at The Institute of Paper Chemistry.

Table I. Summative Analysis of Tupelo Woods

	Black tupelo (Nyssa sylvatica *March*)		*Water tupelo* (Nyssa aquatica *L.*)	
	Sapwood, %	*Heartwood*, %	*Sapwood*, %	*Heartwood*, %
Ether extractives	0.44	0.54	0.95	0.88
Alcohol-benzene extractives	2.44	2.41	4.20	4.00
Cold 50% ethanol extractives	1.40	0.88	1.53	2.15
Cold water extractives	0.27	0.32	0.33	0.25
Cold 70% acetone extractives	Not made	Not made	0.12	0.21
Ash	0.65	0.86	0.90	0.71
Acetyl	3.54	2.14	3.74	2.79
Lignin	24.66	26.65	24.90	24.93
Alpha-cellulose corrected for xylan	43.54	43.15	39.99	40.02
Total pentosans calculated as xylan, corrected for uronic anhydride	16.35	16.60	15.75	16.61
Uronic anhydride	4.49	4.98	4.39	4.59
"CH_2" calculated from methoxyl not in lignin[a]	0.89	0.65	0.65	0.60
Total	98.67	99.18	97.45	97.74
Auxiliary Determinations				
[a] Methoxyl in lignin, %	22.89	22.83	22.35	22.78
Methoxyl in extractive-free wood, %	7.96	7.85	7.58	7.54

Table II. Summative Analysis of Tupelo Woods

	Black tupelo (Nyssa sylvatica *March*)		*Water tupelo* (Nyssa aquatica *L.*)	
	Sapwood, %	*Heartwood*, %	*Sapwood*, %	*Heartwood*, %
Ether extractives[a]	0.44	0.54	0.95	0.88
Alcohol-benzene extractives[a]	2.44	2.41	4.20	4.00
Cold 50% ethanol extractives[a]	1.40	0.88	1.53	2.15
Cold water extractives[a]	0.27	0.32	0.33	0.25
Cold 70% acetone extractives[a]	Not made	Not made	0.12	0.21
Ash	0.65	0.86	0.90	0.71
Acetyl	3.54	2.14	3.74	2.79
Lignin	24.66	26.65	24.90	24.93
Alpha-cellulose[b]	44.35	44.11	40.70	40.72
Hemicellulose A	19.02	19.38	17.46	17.62
Hemicellulose B	3.35	2.85	3.00	3.48
Total	100.12	100.14	97.83	97.74

[a] Successive extractions.
[b] Fibrous residue after removal of hemicellulose A (with 5% KOH) and hemicellulose B (with 16% KOH).

In every case, about 1 gram of the mixed extractive-free sawdust was refluxed gently for 7 hr. with 2% H_2SO_4, filtered, cooled, and titrated to about pH 4 with aqueous barium hydroxide (using a pH meter). The acid mixture was filtered and then passed through a column of IR-120 resin. The resulting aqueous solution was concentrated *in vacuo* to a syrup. In each of the four syrups, the mixture was subjected to paper chromatographic separation for 30 hr. using pyridine-butanol-water (10:3:3) as the mobile solvent, drying at room temperature, and then treating further for 24 hr. with a solvent consisting of ethyl acetate-acetic acid-water (9:2:2), air drying, and finally spraying with *p*-anisidine hydrochloride. All four paper chromatograms were quite similar. In each case there was a great preponderance of xylose. There were also appreciable amounts of glucose, galactose, mannose, and arabinose, and apparently slight traces of rhamnose. Appreciable amounts of an aldobiuronic acid [moving at the same rate as 2-α-(4-O-methyl-D-glucuronosyl)-D-xylose] were found and other uronic acids were also present. No other identification of the sugars or uronic acids were made.

Work on the tupelo woods is being continued.

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A New Replica Technique for Making Electron Micrographs of Surfaces of Paper Sheets

JOSEPH J. COMER, HAROLD W. STETSON, and S. C. LYONS

A replica technique which makes possible the electron microscope study of uncoated or coated paper sheets is described. The method consists essentially of preshadowing the paper with platinum, backing the platinum with a film of evaporated carbon, and then dissolving the paper and its coating. The application of this technique to kaolinite coated papers substantiated the conclusions of Woodward and Lyons that the gloss developed by coatings utilizing the finer fractions of kaolinite is caused by preferred orientation of the particles parallel to the surface of the coating. Papers coated with titanium dioxide, calcium carbonate and zinc oxide were also examined by this technique and each is shown to have a characteristic structure. The method may also be of value in studying ink receptivity of various coatings, and in studying adhesives and sizings at the coating surface.

THE best light photomicrographs fail almost completely to reveal the nature and details of the individual pigment particles because the maximum useful magnification is too low. In this connection it should be noted that there are about 500,000,000 individual particles of Premax coating clay per square inch in the first layer of a sheet of paper coated with it. Electron micrographs have shown that kaolin particles under 2 mu in diameter exist as thin hexagonal plates with a thickness approximately $^1/_{10}$ of the equivalent circular diameter of the crystal. Woodward and Lyons (*1*) in a study of particle shape versus particle size of kaolinite greater than 2 mu found that the larger particles consist mainly of aggregates of the single crystals, resembling stacked poker chips. Titanium dioxide (commercial pigment) is in the form of very fine, rounded units. Precipitated calcium carbonate consists of rhombic crystals of calcite with large agglomerates, and zinc oxide has been shown to be mainly acicular and columnar in shape.

From electron microscope studies of various size fractions of kaolin in the dispersed state, Woodward and Lyons theorized that fine particle-size clays develop their characteristic high gloss and opacity by virtue of the fact that they consist predominantly of flat plates which settle from the coating color in a position parallel to the paper web. Conversely, it was postulated by these authors that the more nearly equidimensional "stacks" associated with the greater-than-2-mu fraction assume a more random orientation and hence do not develop as much gloss because the edges of the composite plates are often normal to the coating surface and cause scattering of the incident light.

Nevertheless, it was not possible to study by electron microscopy the surface of a coated sheet in order to confirm the hypothesis mentioned above prior to the development of the replica technique about to be described.

For the benefit of those who may not be familiar with the principles and limitations of electron microscopy it may be appropriate to discuss the matter briefly before describing the technique.

Contrast in an electron microscope image depends upon scattering of electrons by the specimen, creating differences in the number of electrons passing through various parts of the specimen. These differences in transmission depend in turn upon the thickness of the specimen, its density, and its composition. Because of the low penetrating power of the electron beam, the specimen must be very thin, of 0.2 mu or less in thickness, in order for detail to be seen. Thus, the only method for examining the surface of solids such as paper, glass, metals, and clays is to make a replica of that surface. The replica can be a plastic film prepared on the surface in the desired thickness so as to follow the contours of the surface. It can be stripped from the surface and examined in the electron microscope. Differences in the thickness of the plastic, corresponding to elevations or depressions in the specimen, control the number of electrons passing through the various areas and show the topography of the specimen. In order to increase contrast, the sample is shadow-cast with a thin film of metal deposited at a known angle by means of vacuum evaporation. The "shadows" cast by elevated areas of the specimen appear light on the micrographs. A detailed discussion of the shadow-casting technique is included in a paper by Williams and Backus (*2*).

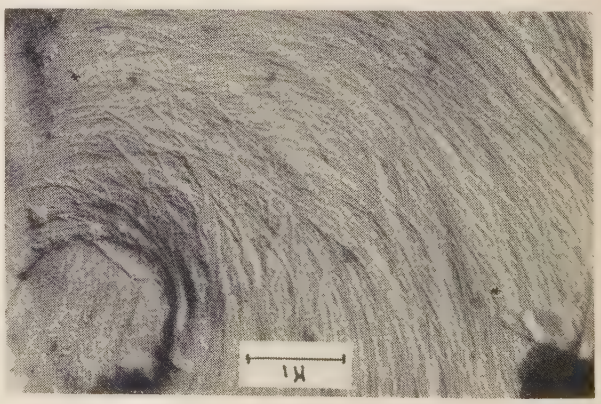

Fig. 1. Surface of uncoated paper; preshadowed silica replica

The replica may also be formed by evaporating silica (silicon dioxide) or silicon monoxide onto the surface of the specimen and then dissolving the specimen. Such

JOSEPH J. COMER, Assistant Professor of Mineral Sciences; HAROLD W. STETSON, Research Assistant, Mineral Constitution Laboratories, The Pennsylvania State University, University Park, Pa.; and S. C. LYONS, Technical Director, Georgia Kaolin Co., Dry Branch, Ga.

replicas proved to be quite satisfactory for uncoated paper (Fig. 1). However, neither this replica technique nor the plastic replica technique could be applied to the study of coated paper because of the porosity of

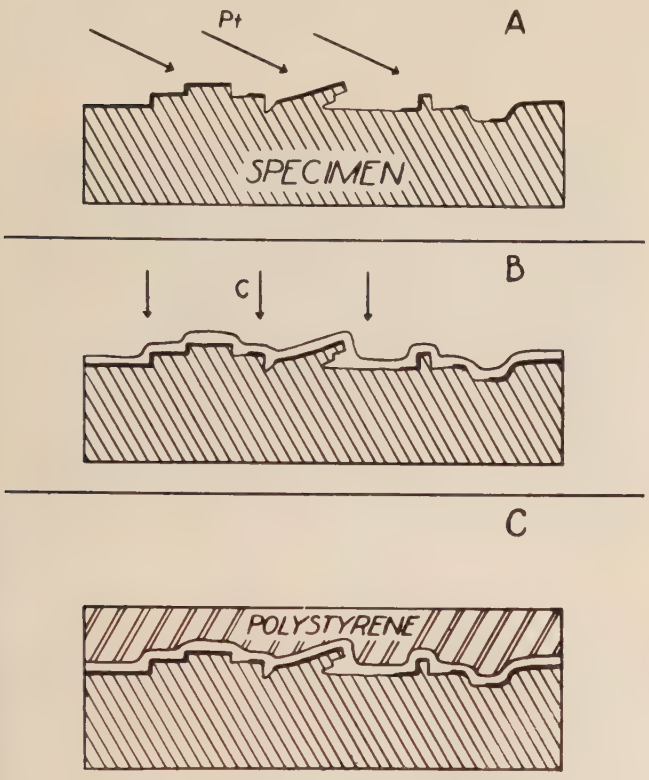

Fig. 2. Steps in the preparation of preshadowed carbon replicas of paper surfaces

the sample and the necessity of using hydrofluoric acid to dissolve the clay coating.

A NEW REPLICA TECHNIQUE FOR COATED PAPER

The technique which proved satisfactory was a modification of a replica method developed for the study of bulk clays by Comer and Turley (*3*) and used by Bates and Comer (*4*) to study various bulk clays.

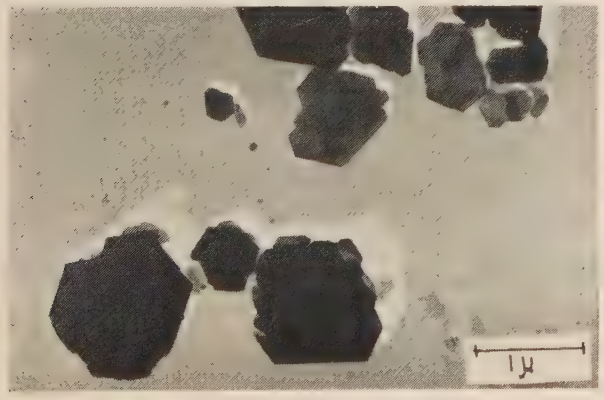

Fig. 3. Fine particle coating clay dispersed on collodion substrate

Figure 2 shows the main steps in the preparation of the replica. The specimen may be about $^1/_2$ in. square, mounted on a glass slide. A film of platinum, approximately 5 to 10 A in thickness, is deposited on the specimen by high-vacuum evaporation. The angle of incidence may be varied. Angles of 10 to 20° help to show very fine structure while angles of about 45° will be suitable for coarser surfaces. If desired, a second

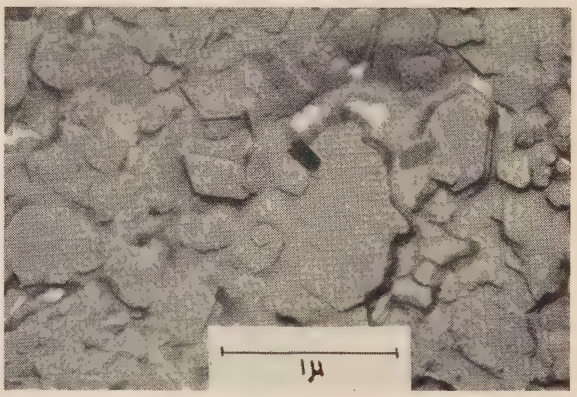

Fig. 4. Surface of paper with fine-particle coating clay; preshadowed carbon replica

shadowing film may be applied at a different angle of incidence in a different direction from the first. Next the specimen is coated with an evaporated film of carbon by striking an arc in vacuum between two carbon rods using the method described by Bradley (*5*). The thickness is determined by trial and controlled roughly by observing the color of the deposited film on a glass slide. In most cases films about 100 A thick are suitable.

The specimen is embedded in a disk of polystyrene about 1 in. in diameter and 1 to 2 mm. in thickness. These are formed by heating polystyrene granules on a glass slide placed on a hot plate. A second slide is placed over the top and pressure is applied to squeeze

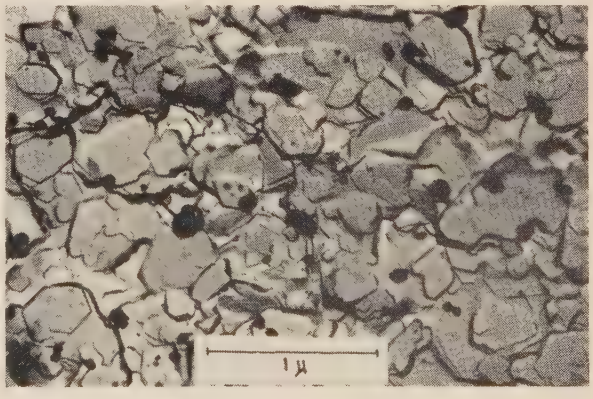

Fig. 5. Surface of page from "slick" magazine; preshadowed carbon replica

the softened plastic into a disk of the desired diameter. After cooling, the top slide is removed and the disk on the bottom slide is again heated on a hot plate until soft. The paper is placed on the disk with the replica side in contact. Using another glass slide on top of the paper, pressure is applied to obtain intimate contact between the replica and the plastic. Care must be exercised to avoid pressing the paper itself into the

plastic. Upon cooling the disk can be separated from the slides. Inspection through the disk will indicate if good contact has been achieved.

After the paper has been embedded in the polystyrene the exact treatment will depend on the nature of the

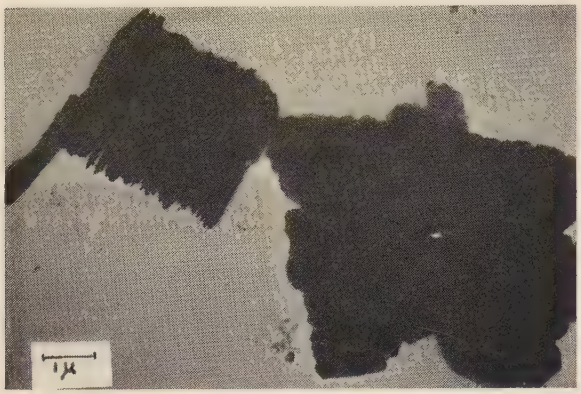

Fig. 6. Greater-than-2-mu fraction of kaolinite dispersed on collodion substrate

pigment and the type of sizing used. The following series of steps has been found effective for the limited number of papers which have been examined.

Treatment to Remove Sizing

The polystyrene disk is placed in warm 5 to 10% NaOH for an hour or two. For a stubborn case of starch or gelatin a solution of an enzyme such as pepsin or Taka-Diastase should prove effective, although this treatment has not yet been found to be necessary.

Removal of Paper

Once the sizing agent has been dissolved, the paper web may usually be peeled from the disk with no difficulty. In the event of thin coatings or no coating at all, where the actual fibers are in contact with the rep-

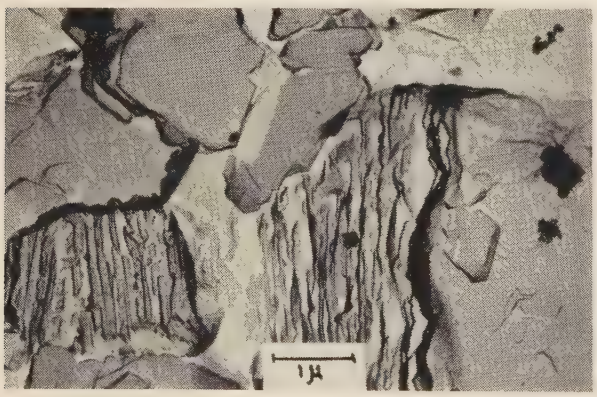

Fig. 7. Surface of paper hand-coated with greater-than-2-micron kaolinite; preshadowed carbon replica

lica, the paper will not peel off but must be removed by solution in concentrated sulphuric acid. This will be accelerated if most of the paper not in immediate contact with the plastic is removed with tweezers after the sizing has been dissolved.

Removal of Pigment

After the paper is removed, the pigment may be dissolved in a suitable solvent. For example, clay and titanium dioxide are soluble in hydrofluoric acid, while zinc oxide and calcium carbonate will dissolve in sulphuric acid.

The polystyrene disk is now washed in distilled water and allowed to dry thoroughly. The replica is scored into $^1/_8$-in. squares which are floated off in ethylene dichloride. By means of an eye dropper the squares

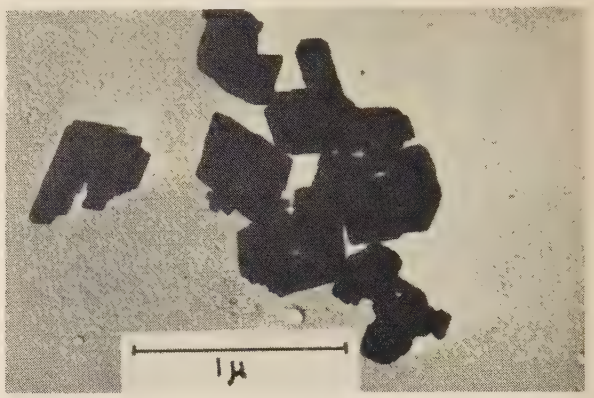

Fig. 8. Precipitated calcium carbonate dispersed on a collodion substrate

are placed in fresh ethylene dichloride for washing and then caught on the usual copper screens for observation in the microscope. This last step is the same as that employed in the removal of silica films in the polystyrene-silica replica technique (*6*).

Results of Replica Studies

The series of electron micrographs shown in this article represent surfaces of sheets coated with various pigments commonly used in the coating of paper. These will include fine-particle (high gloss) coating clays, medium fine coating clays, calcium carbonate (precipitated), commercial titanium dioxide papermaking pigment, and zinc oxide. In each case a micrograph of a

Fig. 9. Surface of paper hand-coated with precipitated calcium carbonate; preshadowed carbon replica

dispersion of the pigment itself is included to enable a comparison with the pigment as it appears on the surface of the paper.

The first of these is a commercial sheet coated with one of the finest commercial clays of small particle size.

Figure 3 shows a dispersion of the clay, while in Fig. 4 the actual coating on paper is seen. It should be noted that the earlier predictions regarding formation of an overlapping "fishscale" pigment structure are confirmed. Further indications of this structure are seen in Fig. 5 showing the surface of a page removed from one of the many "slick" type magazines on the market.

In examining the greater-than-2-mu fraction, Fig. 6,

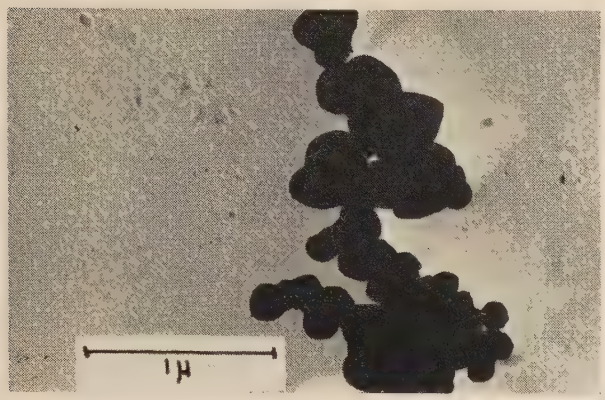

Fig. 10. Commercial titanium dioxide dispersed on collodion substrate

of the kaolin prepared by dispersion techniques, a profound difference is seen in the thickness. The stacked plates form a particle which is essentially equidimensional. Figure 7 shows the appearance of a sheet hand-coated with these particles. Note the absence of the overlapping structure and instead the much coarser surface produced by particles showing a more random orientation. It is of especial importance to note the stack lying edgewise showing clearly the laminated structure characteristic of the coarser-than-2-micron particles. Particles showing this orientation were found throughout the surface of the entire sheet of paper.

It will hardly be necessary to enlarge upon the reason why the "self-orientating" minute (<2 mu diameter)

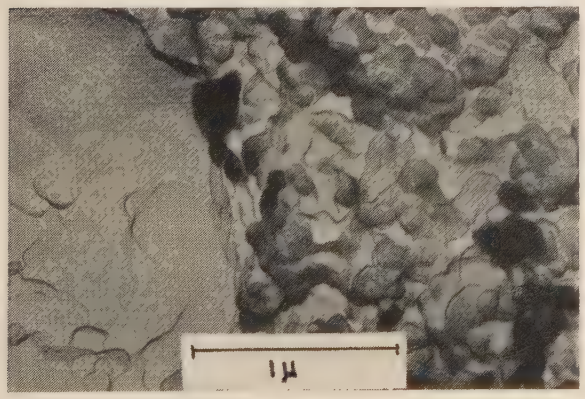

Fig. 11. Surface of paper hand-coated with commercial titanium dioxide; preshadowed carbon replica

platy clay particles yield very glossy sheets, even with a minimum of calendering.

The reasons why these platy particles produce very opaque coatings are likewise apparent. Single hexagonal platy crystals of kaolinite seldom are found larger than about 2 mu in diameter and their thickness is only about 0.2 mu. At the same time, even an 8 lb. (per ream) coating is about 10 to 15 mu thick, which means that 20 or 30 overlapped clay plates can be

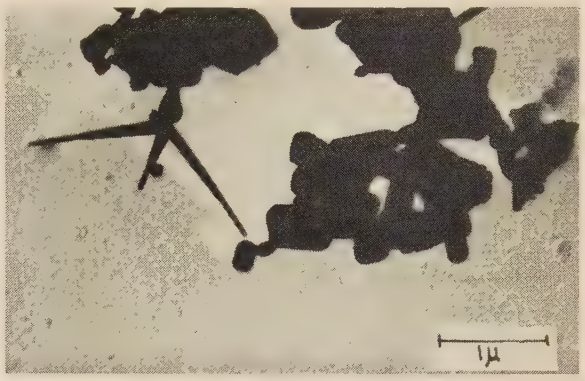

Fig. 12. Zinc oxide dispersed on a collodion substrate

embodied in orientation parallel to the paper web within the cross section of the coating film.

A simple demonstration of this principle may be had by wrapping tightly around a black object (such as a pen holder) about 20 turns of a thin, clean, cellophane tape. The opacity of the multilayer winding will be such that the pen holder cannot be seen through it. On the other hand, a single strip of cellophane as thick as the multilayer roll will be quite transparent.

This also explains why high adhesive ratios usually reduce opacity, because they tend to fill the interfacial voids between the plates, thereby displacing the air between them (refractive index 1.0) with starch or casein whose index is much more nearly equal to that of the clay particles (1.56).

It is further easily seen why the fine-particle clays

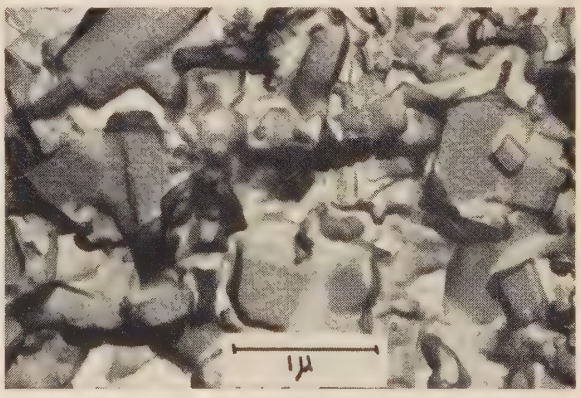

Fig. 13. Surface of paper hand-coated with zinc oxide; preshadowed carbon replica

yield coatings which produce gloss-ink effects and good varnish holdup. Comparison of the "knurled" or "embossed" surface of the sheet coated with the tiny rhombohedral crystals of calcium carbonate (calcite) will, it is believed, suggest a more porous and ink receptive surface. The same is true of the zinc oxide, and the coarser clay, and to a lesser degree the titanium dioxide.

MICROGRAPHS OF COATINGS WITH TITANIUM DIOXIDE, CALCIUM CARBONATE, AND ZINC OXIDE

Figure 8 shows the pigment calcium carbonate. Figure 9 shows the surface of a sheet hand-coated with

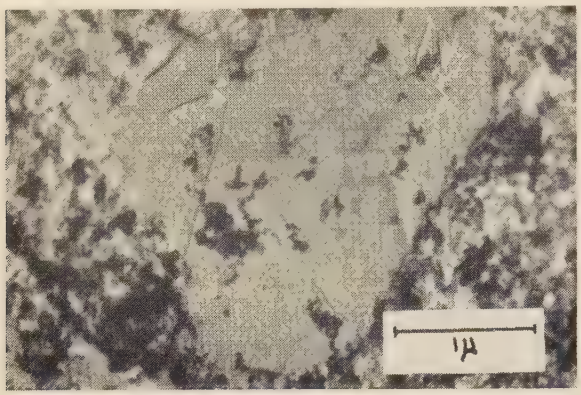

Fig. 14. Ink distribution on printed sheet of kaolinite-coated paper; preshadowed carbon replica

this pigment. The typical rhombic crystal form of calcite can be seen more clearly than in the dispersed pigment.

Figure 10 shows a dispersion of commercial titanium dioxide. These clusters of rounded particles are typical of this material. Figure 11 shows a sheet hand-coated with this pigment. The rounded units are clearly evident. The smooth area to the left shows the pigment particles completely covered by the matrix material leaving only a suggestion of their presence. This is in sharp contrast to the appearance of the kaolin coatings where the individual particles are sharply outlined.

In Fig. 12 is shown a dispersion of the zinc oxide particles. Note both the needle formation, or acicular shape, as well as the columnar-type particles. In

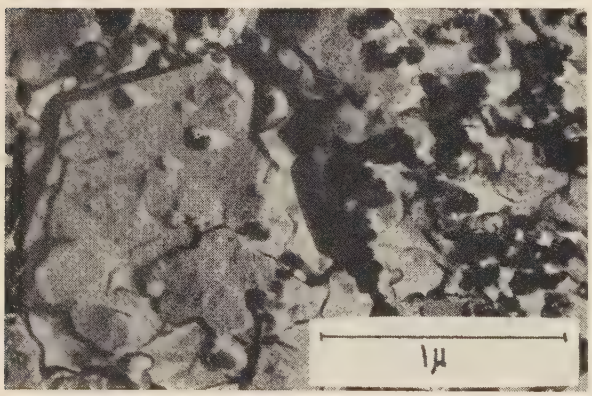

Fig. 15. Ink distribution on printed sheet of kaolinite-coated paper; preshadowed carbon replica

Fig. 13, showing a coating, the same crystalline forms are clearly seen. This micrograph should make it clear why such coatings are of low gloss and high ink receptivity.

DISTRIBUTION OF INK AT THE SURFACE

The last two figures will indicate how ink receptivity might possibly be studied by this technique. The particles of carbon black or lamp black are retained by the replica and appear as dark specks. Where the particles have been lost their outline is shown by the replica. Note in Figs. 14 and 15 the absence of the ink on the surface of the single large particle in this field. Because of the unusually large size and irregular shape particle a guess would be that it is mica. In any case of this the ink apparently does not wet the surface of this material as it does the kaolin.

FURTHER STUDIES

Present studies have been so revealing that they have suggested as many questions as they have answered. Therefore, further studies somewhat along the same lines are planned.

For example, replicas of cross sections of coated sheets may reveal interesting structural details and/or the distribution of adhesive, as between the coating film and the web.

Further studies are planned in an effort to resolve, with greater detail and certainty, the location of the adhesive and the nature of its interfacial relationship with the pigment particles. In other words, is it absent from the faces of the kaolin particles; does the ink take to the clay preferentially, etc.?

Micrographs of sheets, before and after calendering, should throw light upon what happens to the surface of sheets (when coated with different pigments) upon supercalendering.

The present series of micrographs were prepared from sheets which had been coated with a single pigment, but it may be instructive to study coatings prepared from mixed pigments, for example, fine-particle clay plus titanium dioxide, etc.

SUMMARY

The explanation for the mechanism of gloss development in clay-coated paper sheets previously postulated by Woodward and Lyons has been confirmed. In addition it is felt that the technique adequately fills the need for a reliable method of examining the surfaces of paper and other porous materials at high magnification and permits one to study, for example: (1) pigment distribution and size at the surface; (2) ink receptivity; (3) other mineral distribution and size; (4) matrix coating of the pigment.

Knowledge of these should be of great value to the paper coater who wishes to use the technique for quality control or improvement of his product.

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Contribution No. 55-3 from the College of Mineral Industries, The Pennsylvania State University, University Park, Pa.

Brightness Reversion of Bleached Kraft Pulps

SAMUEL M. ROLLINSON

A study was made of the brightness reversion, or yellowing, which occurs when bleached kraft pulps are heated. The pulps used were all prepared from slash pine kraft pulp by a bleaching sequence of chlorination, caustic extraction, calcium hypochlorite oxidation, caustic extraction, and calcium hypochlorite oxidation. Extensive washing, thorough caustic extraction, and the maintenance of high pH during the hypochlorite stages were all found to reduce reversion. The yellowing tendency of a fines fraction (average fiber length 0.7 mm.) was shown to be only 70% that of the unfractionated pulp (average fiber length 2.4 mm.). The presence of added iron was found to increase the extent of brightness reversion, but attempts to increase color stability by the removal of the iron normally present in pulp with Versene (an organic chelating agent) or by hydrochloric acid extraction were unsuccessful.

Brightness is defined as the reflectivity of a sheet of pulp or paper for blue light measured under standardized conditions. It is well known that the brightness of bleached pulps is not permanent and that brightness reversion (fading, yellowing, color recession) is accelerated by exposure to light, heat, chemicals, and high humidities. Many statements concerning the causes of brightness reversion have been advanced largely on the basis of qualitative observations. However, this phenomenon has not been studied extensively, as have some of the other phases of pulp and paper technology.

Brightness reversion is relatively important commercially for several different but related reasons. Disputes naturally arise between the parties involved in the sale of a pulp if the brightness of that pulp decreases in transit. This is the *only* chemical or physical property of pulp which can change significantly under the conditions, and within the relatively short time interval involved during shipment. The yellowing or fading of pulp directly counteracts the results of the expensive bleaching operations. Since the bleaching cost per unit brightness increases rapidly as higher brightness values are attained, even a slight amount of yellowing of very bright pulps is disheartening to the producer. Perhaps the most important economic aspect of this subject lies in the relationship of color stability to the creation of new markets for bleached wood pulps. Only in recent years, as bleaching has been more thoroughly developed, have bleached wood pulps been able to compete successfully with rag or cotton pulps for end uses requiring a high degree of strength and color permanence.

Prior to the studies of Tongren (*1*), work done on the problem of brightness reversion was largely of a qualitative nature. A few of the papers since that time on this subject are reviewed briefly in the following paragraphs.

Tongren (*1*) made a study of the accelerated discoloration of both unsized and rosin sized sulphite papers. Rosin sizing was shown to effect a significant increase in the extent of yellowing. From the data obtained, Tongren concluded that the Kubelka and Munk number, k/s, is linearly related to the square root of aging time; therefore, the rate of discoloration was expressed as the slope of this curve. Removal of the natural resins of pulp was shown to decrease the reversion rate slightly. Purification of sulphite pulp by caustic extraction was found to greatly increase color stability. At 100°C. and above 25% R.H., increasing humidity was shown to increase the aging rate linearly.

McIntyre (*2*) found that the accelerated rate of discoloration versus the humidity curve for a particular bleached Mitscherlich pulp had a minimum point at about 20% R.H. Several other pulps did not show this minimum rate; thus, relative humidity does not exert a proportional effect on the reversion rates of different types of pulp. It was postulated, but not proved that accelerated aging would most nearly parallel natural aging if a normal amount of moisture was maintained in the sheet. Accordingly, 95°C. and 55.4% R.H. were adopted as standard aging conditions. Heat in the presence of excess moisture, a condition which exists during the machine drying of pulp and paper, was found to increase color stability. Prolonged wet storage was shown to decrease the accelerated aging rate, while dry storage was without effect.

In a study of the brightness reversion of sulphite papers Giertz (*3*) showed that extractable resin is of secondary importance and presumably of even less importance in sulphate pulps due to the smaller quantities present. On the basis of experimental data Giertz believes yellowing is not due to lignin. He showed that a linear relationship exists between the product of copper number and carboxyl content, and the reversion rate and stated that oxidative attack resulting from the maintenance of a low pH during hypochlorite bleaching decreases color stability. Giertz found in one instance that the short pulp fibers, or fines, had a lower color stability than the long fibers of a bleached sulphite pulp.

The problem of brightness reversion is still unsolved. It is impossible for one investigator to study all facets of this problem due to the diversity of variables. For this reason the present study has been limited to a single type bleached slash pine kraft pulp prepared by conventional methods. This choice was based on the rapid growth of the bleached kraft pulp industry in the south. It has been stated that these pulps show a greater yellowing tendency than sulphite pulps. This statement is, of course, difficult to evaluate properly without data representative of these pulps, and no attempt has been made in this study to determine the differences (if any) in the reversion characteristics of these two major bleached chemical wood pulps.

Samuel M. Rollinson, The Institute of Paper Chemistry, Appleton, Wis.

Until recently nearly all of the bleached kraft pulp in this country has been produced by a conventional five-stage system utilizing an acid chlorination, a sodium hydroxide extraction, an alkaline calcium hypochlorite bleach, another caustic extraction, and another calcium hypochlorite bleach in that order. Today, chlorites, chlorine dioxide, and peroxides are being used to supplement or replace calcium hypochlorite for bleaching since they give pulps of higher original brightness, greater strength, and greater color stability. However, the bleaching effect obtained with these agents is more expensive than that obtained by the customary calcium hypochlorite, and in this study primary consideration has been given the conventional five-stage bleach.

Only brightness reversion accelerated by heat was studied in this work. McIntyre found that the correlation between such yellowing and that occurring on natural aging is poor (*2*), but since heat is used in processing pulps and papers, in drying, sterilization, and various conversion methods, such a study is well justified.

STANDARD METHODS AND MATERIALS

Unbleached Pulp

All experimental work was conducted with a single lot of unbleached slash pine kraft pulp which was prepared in a laboratory digester under conditions similar to those used in commercial practice.

Bleaching Chemicals

Only C.P. chemicals were used in all bleaches to prevent the introduction of iron or other contaminants. Calcium hypochlorite solution was prepared from chlorine water and calcium hydroxide immediately before using; any undissolved calcium hydroxide was removed by filtration. The total available chlorine concentrations of all bleach liquors were determined by TAPPI Standard T 611 m-47.

Bleaching

High Consistency. In order to prepare 750 to 1500 grams of bleached pulp, the bleaching stages were conducted under the following conditions, which are similar to those used commercially. These conditions became the standard after experimental work demonstrated that they would result in an 80 to 85% G.E. brightness pulp.

The chlorination was carried out in a rubber-lined vessel fitted with a draft tube and a stainless steel propeller for agitation. Chlorine was added in the form of freshly prepared chlorine water, the concentration of which was determined by titration. At the conclusion of the chlorination the pulp was washed on a cloth drain box until the washings were neutral and free of chlorine.

The caustic extraction was conducted in a Pfaudler glass-lined mixer heated by water circulating through a jacket. The pulp and caustic solution were mixed thoroughly at the beginning of the extraction stage and were stirred frequently. This stage was concluded by washing the pulp on a cloth drain box until the washings were essentially colorless and at the same pH as the wash water. The tap water used for high-consistency bleaching had a pH value of about 9.

Earthenware crocks heated in a constant temperature bath were used for the hypochlorite stage. The pulp slurry was stirred manually. The pH was checked frequently with a Beckman glass electrode pH meter and was maintained at 9.5 to 8.5 by the addition of small amounts of sodium hydroxide solution. At the conclusion of the hypochlorite stage the pulp was washed for about 45 min. on a cloth drain box with a water flow rate of 5 to 10 g.p.m. It was then soaked overnight at 1% consistency, and the bleaching sequence was continued on the next day.

Table I. Conditions for High-Consistency Bleaching

Treatment	*Chemical added (pulp basis), %*	*Consistency, %*	*Temperature, °C.*	*Time, min.*	*pH*
Chlorination (C)	6.00	3.0	23 ± 2	60	...
Caustic extraction (E)	2.50	10.0	60 ± 5	60	...
Calcium hypochlorite (H)	1.50[a]	5.0	40 ± 0.5	240	9.5–8.5
Caustic extraction (E)	0.75	10.0	50 ± 5	120	...
Caldium hypochlorite (H)	0.50[a]	5.0	40 ± 0.5	240	9.5–8.5

[a] Expressed as chlorine.

The second caustic extraction stage was carried out in the same manner as the first extraction, and the second hypochlorite stage was also similar to the first. After the CEHEH pulp had been soaked at 1% consistency overnight, it was again washed thoroughly, filtered on a Buchner funnel, and stored at 25 to 35% consistency in polyethylene bags at 9°C.

Low Consistency. For the preparation of 10 to 20 grams of pulp the bleaching stages were conducted at 1% consistency. This low consistency was necessary for the efficient handling and agitation of these small quantities of pulp. The conditions shown in Table II were maintained.

Table II. Conditions for Low-Consistency Bleaching

Treatment	*Chemical added (pulp basis), %*	*Consistency, %*	*Temperature, °C.*	*Time, min.*	*pH*
Chlorination (C)	6.50	1.00	23 ± 2	60	...
Caustic extraction (E)	25.0	1.00	55 ± 0.5	60	9.5–8.5
Calcium hypochlorite (H)	1.50[a]	1.00	40 ± 0.5	240	...
Caustic extraction (E)	7.85	1.00	50 ± 0.5	30	9.5–8.5
Calcium hypochlorite (H)	0.50[a]	1.00	40 ± 0.5	240	...

[a] Expressed as chlorine.

The percentage sodium hydroxide used in the caustic extraction stages of the low-consistency bleaches was increased over that for the high-consistency bleaches in order to give the same concentration of caustic in solution in both cases. No adjustment was made for the concentration of calcium hypochlorite in the low-consistency bleaches and this resulted in slightly lower chlorine consumption.

All stages were conducted in 2-liter brown-glass stock bottles. Continuous agitation was maintained for thorough mixing but at a slow rate to prevent "beating" of the fibers. The reaction bottles were immersed in a constant temperature bath for temperature control.

At the conclusion of each reaction stage the pulp was filtered and washed thoroughly with distilled water. During the hypochlorite stages the pH was maintained at 9.5 to 8.5 by the addition of small amounts of sodium hydroxide solution. After a thorough washing following the second hypochlorite stage, the pulp was soaked in water overnight at 1% consistency; it was then again washed thoroughly, diluted to 0.1% consistency, and made into brightness handsheets.

Sheet Formation

Brightness sheets were prepared according to TAPPI Standard T 218 m-48 with the following modifications: The pulp slurry was filtered on three sheets of 15-cm. filter paper instead of one to prevent the brightness sheet from conforming to the holes in the Buchner funnel. After pressing 5 min. at 50 p.s.i., the three sheets of 15-cm. filter paper were replaced with one sheet of 18.5-cm. filter paper, and the sheets were again pressed at 50 p.s.i. for 1 min. After air drying for 3 to 4 hr, each sheet was cut into four 2-in. squares and a $^1/_4$-in. hole was punched on one side so that each square could be suspended from a glass rod. The squares were then evenly spaced along the rod and placed approximately in the center of the aging oven.

Accelerated Aging

For the accelerated aging of the brightness sheets a CENCO electric oven was used which was cylindrical, 15 in. in diameter by 12 in. deep. The oven temperature cycled over a 2°C. range at 100°C. and completed a cycle in approximately 5 min.

Air was passed through a preheater composed of 5-mm. glass tubing wound with nichrome wire and asbestos insulation before it entered the oven. By adjusting a voltage regulator the air could be preheated to any desired temperature. This prohibited moisture condensation during aging runs made at various relative humidities. To obtain a relative humidity of approximately 0%, the air was first passed through a tube filled with anhydrous calcium chloride; for other humidities a saturator was used.

Unless otherwise specified, all accelerated aging was carried out at 100°C. and essentially 0% R.H. for 2 hr.

Reflectance Measurements

All brightness measurements were made by means of a General Electric reflection meter which was in agreement with the master instrument located at The Institute of Paper Chemistry. A pad of 16 squares was used for each brightness value, and one reading was made for each sheet. The procedure differed from TAPPI Standard T 452 m-48 only in the number of readings made.

Determination of Reversion Rate

The numerical value of the extent of brightness reversion is expressed as $\Delta k/s$ by 10^4. The relationship between reflectivity and k/s developed by Kubelka and Munk has been presented by Steele (*4*). This relationship is:

$$k/s = (1 - R_\infty)^2/2R_\infty$$

k = the absorption coefficient of the sheet
s = the scattering coefficient of the sheet
R_∞ = the reflectivity of the pad of paper expressed decimally against magnesium carbonate considered as 0.98.

Tongren (*1*) found that the number s is considered to be nearly constant throughout the course of aging, so that the change in k/s, $\Delta k/s$, expressed the change in the light absorption capacity of the sheet.

In their studies of the brightness reversion of sulphite pulps, Tongren (*1*) and McIntyre (*2*) expressed the rate of reversion as the slope of the graph of k/s versus the square root of the aging time since this relationship was nearly linear. In this paper the measure of discoloration is not expressed in this manner since the relationship was found to be nonlinear for the aging conditions used. The standard reversion is expressed as the increase in k/s, $\Delta k/s$, for an aging time of 2 hr. at 100°C. and 0% R.H.

EXPERIMENTAL RESULTS AND DISCUSSION

Preparation of Unbleached Pulp

In order to have a uniform pulp supply of known history, a single lot of approximately 50 lb. of an unbleached kraft pulp was prepared in the following manner:

One hundred and five pounds (oven-dry basis) of $^1/_2$-in. slash pine chips were pulped in an A. O. Smith stainless-steel-lined tumbling digester under the conditions, and with the results, given below.

Table III. Pulping Data

Charge, kg.	47.5
Liquor/wood ratio, ml./g.	4.5
Active alkali NaOH + Na_2S (as Na_2O), %	20
Sulphidity Na_2S/NaOH + Na_2S all as Na_2O, %	20
Maximum temperature (false pressure relieved at 100°C.)	170
Time to maximum temperature, hr.	2
Time at maximum temperature, hr.	2
Pressure at blowdown, p.s.i.	80
Screenings, %	0.18
Permanganate number, %	17.1
Lignin content, %	4.2
Original brightness, G. E., %	22.3

The pulping conditions and analytical constants all show the product to be a typical, bleachable grade of slash pine kraft pulp, hence suitable for this study. The screened, unbleached pulp was stored at 30 to 35% consistency in polyethylene bags in a room held at about 9°C.

Reproducibility of Brightness and Reversion Rate Data

The reproducibility of brightness and reversion rate data was determined to ascertain the number of replicate bleaches and brightness readings necessary to obtain reliable data.

It was shown by application of student's "t" distribution (*5*) that for 16 readings of individual brightness tabs of a pulp in the 80 to 85% G.E. brightness range, the 80% confidence interval was ±0.09 and the 95% confidence interval was ±0.18.

Some attention was given to the effect of bleaching variables on original brightness and brightness reversion in the low-consistency bleaches, and therefore the reproducibility of this type data was determined before proceeding with studies of bleaching variables.

A series of nine low-consistency bleaches was made with three bleaches run per day on three consecutive days. A summary of these bleaches is given in Table IV.

The kraft pulps were prepared by common chlorination, first caustic extraction, and first hypochlorite-stages of 750 grams pulp. The pulp was then divided into three equal portions and second caustic extractions of 0, 1, and 4 hr. were conducted before the final hypochlorite stage. The data for these bleaches (170-A, 170-B, 170-C) are given in Table XIII.

Handsheets prepared from these five pulps were aged simultaneously for 2-hr. periods at 100°C. and relative humidities from 0 to 68%. The reversion data for these pulps are presented in graphical form in Fig. 1.

Table IV. Reproducibility of Laboratory Bleaching

	Group A			Average	Group B			Average	Group C			Average
Pulp no.	149	150	151	149–151	152	153	154	152–154	155	156	157	155–157
Chlorine consumed, %												
Chlorination	4.72	4.75	4.82	4.76	4.84	4.87	4.83	4.85	4.84	4.69	4.75	4.76
1st hypochlorite	1.23	1.19	1.18	1.20	1.18	1.18	1.18	1.18	1.16	1.17	1.18	1.17
2nd hypochlorite	0.26	0.25	0.26	0.26	0.28	0.28	0.28	0.28	0.26	0.27	0.27	0.27
Total	6.21	6.20	6.26	6.22	6.30	6.23	6.29	6.27	6.26	6.13	6.20	6.20
Original brightness, % G.E.	80.2	80.2	80.1	80.2	80.6	81.2	81.5	81.1	82.1	82.3	81.7	82.0
$\Delta k/s \times 10^4$	303	300	307	303	257	264	243	254	250	271	272	264
Standard points brightness drop	8.4	8.5	8.7	8.5	7.4	7.8	7.4	7.5	7.8	8.4	8.4	8.1

For bleaches made simultaneously the original brightness values agree within several tenths of a point and there is a spread of less than 8% of the $\Delta k/s$ by 10^4 value. However, the average reversion values for bleaches conducted on different days had a maximum spread of 18%; consequently, for all work in which bleaching or processing variables were studied, duplicate bleaches were made for each condition, and the various bleaches in a given set were made simultaneously.

Effect of Temperature and Humidity During Accelerated Aging

McIntyre (*2*) suggested that accelerated aging should be conducted at 95°C. and 55% R.H. to obtain the best possible correlation with natural yellowing since the handsheets retain a normal amount of moisture under these conditions.

Table V. Ratios of Reversion Rates of Three Kraft Pulps

R.H., %	*170-A*	*170-B*	*170-C*
0	100%	67%	59%
8.5	100	69	58
22.6	100	67	54
37.3	100	68	56
68.2	100	68	60
	Average	68 ± 1	57 ± 2

In this work the effects of temperature and humidity on the reversion rates of bleached kraft pulps were determined in order: (1) to detect similarities or dissimilarities in the comparative yellowing rates of bleached kraft pulps and bleached sulphite pulps, and (2) to ascertain the possible advantages of determining accelerated reversion at any particular relative humidity.

Five bleached pulps were used—three laboratory-prepared kraft pulps, a commercial Mitscherlich spruce pulp, and a commercial sulphite mixed hemlock and spruce pulp with original brightness values of 81.6, 84.3, 84.5, 80.5, and 87.0, respectively.

If the data for bleached slash pine kraft pulps 170-B and 170-C are recalculated as percentages of the reversion rate of pulp 170-A, assuming it to be 100% for all humidity intervals, it can be seen from Table V that these percentages are constant throughout the humidity range studied.

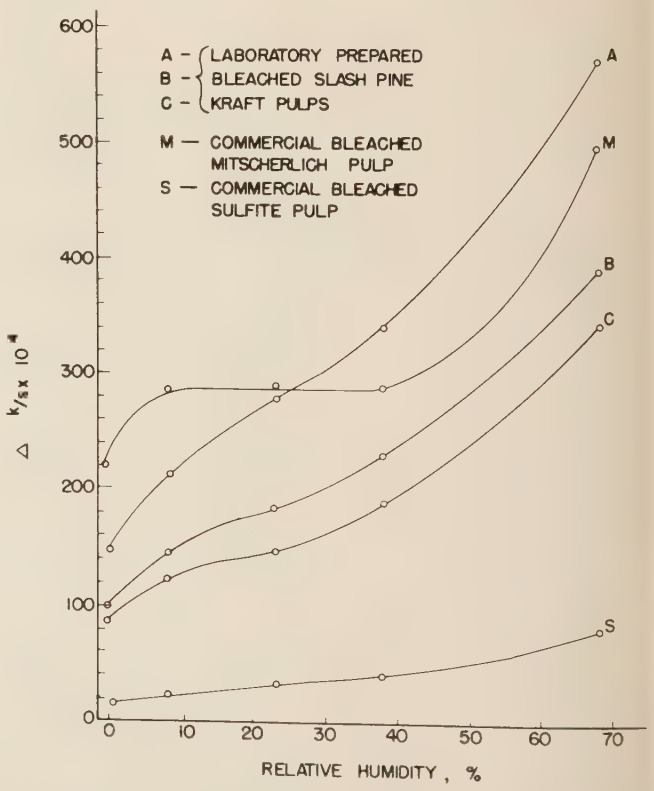

Fig. 1. Pulps aged at 100°C. for 2 hr. at various relative humidities

This fact is significant since it shows that there can be no possibility of better correlation with natural aging on aging at any particular relative humidity since the pulps are rated in an identical manner throughout the range. However, accelerated aging at essentially 0% R.H. is advantageous from the standpoint of easy humidity control, while high humidity aging conditions would be advantageous in the reduced length of time required to obtain a given $\Delta k/s$ value.

The marked difference in the shape of the curves for the Mitscherlich and kraft pulps presents an obvious difficulty in rating the stability of different type pulps; at humidities on either side of the intersection of these curves, these pulps would be rated in reverse order.

Bleaching Variables and Rate of Reversion

Washing. The washing operation at the conclusion of the five bleaching stages removes both inorganic and organic materials. These "bleach residues" allegedly consist of ash, low molecular weight carbohydrates, carbohydrate degradation products, and lignin degradation products, all of which have been considered as causes of subsequent yellowing after the bleaching operation; therefore, washing studies were conducted both to understand the relationship of washing to yellowing and also to aid in the development of a reproducible laboratory bleaching technique. Only distilled water washing has been considered; soaking and washing with acidic solutions has not.

Some criterion of the thoroughness or degree of washing was needed and in this study the relative amounts of carbohydrates present in the wash liquors were determined by a colorimetric method with orcinol (*6*)

It was necessary to completely remove all pulp fibers from the filtrate since they could cause large errors in the determination. Twenty-five milliliters of cold 90% H_2SO_4 and 2 ml. orcinol solution (0.200% orcinol in absolute ethanol) were slowly added to 10 ml. of chilled filtrate in a 100-ml. test tube. The mixture was agitated by pouring back and forth into another test tube, and it was then heated fo 20 min. in a boiling water bath. It was found that color formation due to the presence of carbohydrates was complete after this interval. The solution was then cooled and the 425 to 430 mmu minimum transmittance value was then determined with the General Electric recording spectrophotometer using a blank of distilled water treated in this same manner. It was shown that the color formed obeyed Beer's Law at the concentrations used. This test procedure gave a transmittance value of 66.4% or an optical density of 0.177 for 0.01% solution of glucose.

All washing studies were begun immediately after the conclusion of the second hypochlorite bleaching stage, since in this manner the effect of diffusion could be detected. The pulps were stored at 9°C. between filtrations to inhibit bacterial attack.

It was found by the orcinol test that an equilibrium was reached in washing liquor concentration after about three washes both immediately after the bleach and also after 6 days soaking. Although the concentration of material in the washings (directly proportional to log $1/T$) diminishes rapidly on continued soaking, it does not reach zero and materials are still dissolving out after the 6-day period. Therefore, on this basis, pulps 147 and 148 were given three successive washes on each of several days. Immediately after bleaching, washing was done at 1% consistency and 40°C. and on succeeding days at 1% consistency and room temperature. The colorimetric orcinol test was applied to only the first of the three filtrates obtained each day. Brightness and reversion data were also obtained and are presented graphically in Fig. 2.

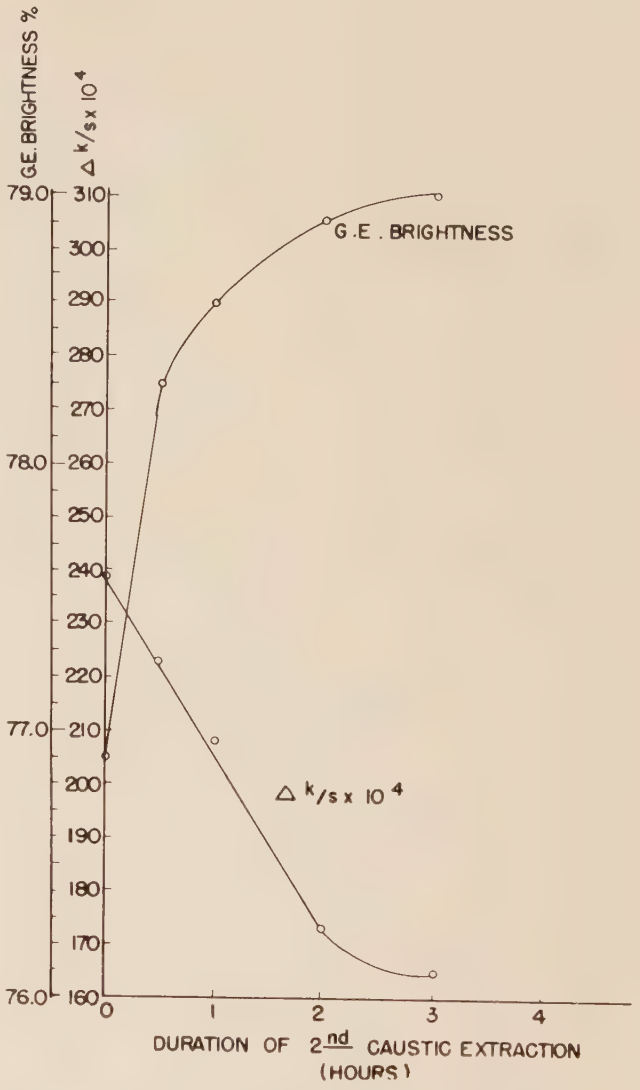

Fig. 2. Effect of caustic extraction on brightness and reversion

These data show that there is a definite lowering and stabilizing of the reversion tendency after *thoroughly* washing the bleached pulp. The diffusion of constituent from within the fiber is relatively slow and therefore several days are necessary for complete pulp washing. Although this indicates that the $\Delta k/s$ values depend on the degree of washing, from the standpoint of comparing bleaches, reproducible data can be obtained if the brightness sheets are formed soon after the pulp is bleached.

Hypochlorite Stage pH. The equilibrium mixture of chlorine, hypochlorous acid, and the hypochlorite ion is known to be affected markedly by pH. At low pH values chlorine predominates, at neutrality hypochlorous acid predominates, and at high pH values the hypo-

chlorite ion is the major component. Obviously then the bleaching reactions involved at different pH values are not identical. Clibbens and Ridge (*7*) showed that, during hypochlorite bleaching of cotton cellulose, carbohydrate oxidation increases as neutrality is approached. In a study of the bleaching of sulphite pulp Giertz (*3*) demonstrated that reversion also increases if hypochlorite bleaching is done under neutral rather than alkaline conditions. The present study was conducted to determine the degree of color stability attainable by highly alkaline hypochlorite bleaching.

The pH was varied in the second hypochlorite stages of bleaches 137 through 145. Inadvertently, the consistency of the chlorination stage was 1.67% instead of 1% resulting in high chlorine consumption (6.2%) for this stage and low chlorine consumption (0.28%) for the first hypochlorite stage. The bleaching data are given in Table XIII and the pH and reversion data are tabulated in Table VI.

Table VI. Effect of pH of Hypochlorite Stage on Reversion

	Bleach number								
	137	*138*	*139*	*140*	*141*	*142*	*143*	*144*	*145*
2nd hypochlorite									
Initial pH	10.6	10.0	9.5	8.9	8.5	8.0	7.5	7.0	6.5
Final pH	10.5	9.6	8.6	8.3	8.0	7.6	7.1	6.6	6.0
Arithmetic av.	10.5	9.8	9.0	8.6	8.2	7.8	7.3	6.8	6.2
Original brightness, % G.E.	82.3	82.6	82.6	83.3	83.2	83.7	83.2	82.9	82.6
Standard $\Delta k/s \times 10^4$	143	153	150	156	160	164	163	174	185

It can be seen that the reversion rate increases if the pH of the second hypochlorite stage is decreased toward neutrality. The reduction in $\Delta k/s$ obtained by bleaching at pH 10 instead of pH 6 is about 20%; therefore, it is apparent that although yellowing can be minimized by bleaching at high pH it cannot be prevented. It is probable that carbohydrate oxidation is to some degree responsible for the yellowing of pulp. It is interesting to note that the maximum brightness was obtained for hypochlorite stage pH of 8 to 7. The same relationships of both brightness and reversion rate to the pH of the hypochlorite stage were found when pH was varied in both hypochlorite stages.

Consistency. Experimental bleaches were conducted at low consistency (1%) and high consistency (3 to 10% for the preparation of 10 to 20 grams and 750 to 1500 grams of pulp, respectively. (See Standard Methods.) There were two major differences other than consistency for these bleaches: (1) The total chlorine consumption was higher in the high-consistency bleaches. (2) The duration of the second caustic extraction stage was 2 hr. for the high-consistency bleaches, but only $^1/_2$ hr. for low-consistency bleaches. The lower chlorine consumption at low consistency was due to the effect of concentration while the extraction time was intentionally reduced since it was thought that at the relatively high dilution the extraction would proceed more rapidly.

Standard $\Delta k/s$ by 10^4 values were about 270 for the low-consistency bleaches while only 130 for the high-consistency bleaches. In order to determine the cause for this, the effect of consistency was first eliminated by preparing triplicate low-consistency bleaches 166, 167, and 168 which differed from the standard low-consistency bleaches in the fact that the chlorine consumptions and all other variables except consistency were held as closely as possible to the conditions for high-consistency bleach 165. The data for these four bleaches are given in Table VII.

The consistency of these bleaches evidently has no effect on reversion. This is of course applicable only to the range studied. The consistency of the hypochlorite stages was 1% for bleaches 166 to 168 and 5% for bleach 165. Aalto (*8*) recently showed that a very pronounced increase in reversion occurs as the consistency of the hypochlorite stage for sulphite pulps is increased from 3 to 12%. This can probably be accounted for by the lack of process control resulting in localized overbleaching and underbleaching, uneven pH, and poor temperature distribution at the higher consistency.

Second Caustic Extraction Stage. The effect of the duration of the second caustic extraction was determined since White and others (*9*) have shown that diffusion of materials from within the fiber during this stage is relatively slow. Low-consistency bleach 169 was carried out using 100 grams which was divided after the first hypochlorite stage into two equal portions for individual bleaching. Duplicate bleaches were made 0, $^1/_2$, 1, and 2 hr. of caustic extraction with a single bleach for the 3-hr. extraction. The data for these bleaches are presented graphically in Fig. 3.

Table VII. Effect of Bleaching Consistency on Reversion

	Bleach number			
	High consistency	*Low consistency*		
	165	*166*	*167*	*168*
Chlorine consumed, %				
Chlorination	5.35	5.39	5.36	5.42
1st hypochlorite	1.38	1.35	1.42	1.43
2nd hypochlorite	0.29	0.17	0.20	0.21
Total	7.02	6.91	6.98	7.06
Original brightness, % G.E.	84.0	82.8	83.8	82.6
Standard $\Delta k/s \times 10^4$	127	141	128	157
Standard points brightness drop	5.1	5.1	5.0	5.5

The extended caustic extraction reduces the rate of reversion by about 30% and increases the brightness by 2%. Evidently the materials removed by this extraction do not consume a noticeable amount of oxidant since there was no variation in the second stage hypochlorite consumption. The brightness gain and increased color stability obtained demonstrate the value of an extended caustic extraction for commercial kraft bleaching. For experimental purposes variations in this stage afford an easy method for the preparation of

pulps with similar chemical characteristics but different color stabilities and different original brightness.

Highly Purified Pulps. The preceding paragraphs have been concerned only with CEHEH bleaching. During the course of preparing hemicellulose, pulp 165 was chlorited by a modification of Jayme's method described by Wise (*10*) and extracted overnight at room temperature (exposed to air) with 10% KOH. According to Kaverzneva (*11*) the chloriting treatment should convert the aldehyde groups formed during hypochlorite bleaching to carboxyl groups. Since such a treatment is known to increase color stability it was of interest to determine the effect of producing more aldehyde groups by subsequent drastic hypochlorite bleaching of the chlorited and the chlorited potassium hydroxide extracted pulps.

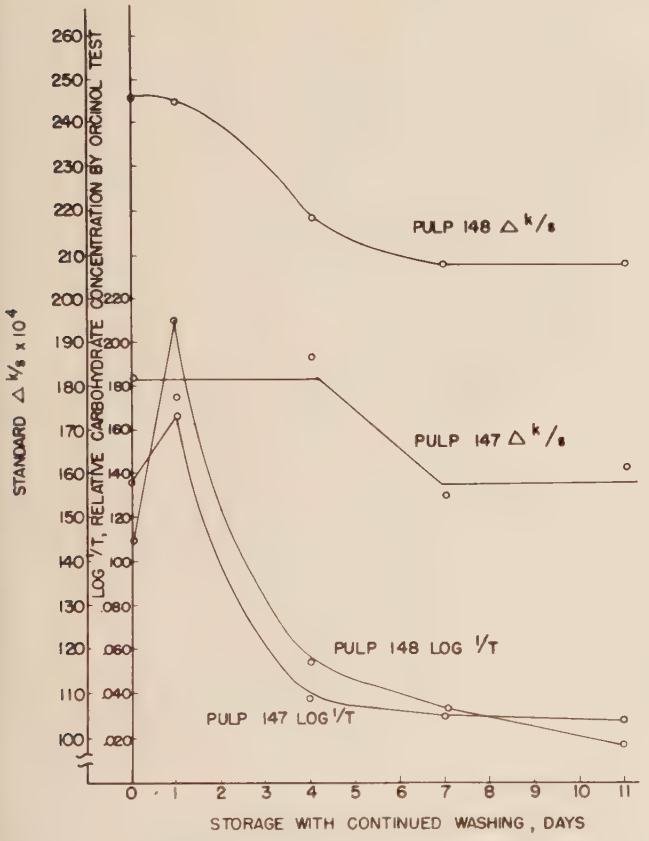
STANDARD Δ k/s x 10⁴
LOG 1/T, RELATIVE CARBOHYDRATE CONCENTRATION BY ORCINOL TEST
PULP 148 Δ k/s
PULP 147 Δ k/s
PULP 148 LOG 1/T
PULP 147 LOG 1/T
STORAGE WITH CONTINUED WASHING, DAYS

Fig. 3. Carbohydrate concentrations of filtrates from washings and effect of washing on reversion rate

The hypochlorite bleaches were conducted at 1.0% consistency, 40°C., 4 hr., pH 7.0 to 6.5 with 1.00% chlorine added.

The additional hypochlorite bleach raised the G.E. brightness by 1 and 3%, respectively, for the chlorited and the chlorited potassium hydroxide extracted pulps, but the $\Delta k/s$ values were increased only slightly! These data indicate that the color precursor is either altered or removed by the acidified chlorite treatment and that subsequent carbohydrate oxidation with hypochlorite has little effect on reversion.

Fiber Length Fractionation Studies

From the preceding sections it is apparent that bleaching variations have a pronounced influence on brightness reversion. One method of eliminating these variables is to study fibers which have been bleached together such as fractions based on fiber length. It has been shown that the other short fibers of hard bleached sulphite pulp yellow to a greater extent than the long fibers; Giertz (*3*) attributed this difference to overoxidation of the fines during bleaching. Braun and Rollinson (*12*) found the short fibers of bleached kraft pulp to have greater color stability than the long fibers. It should be possible by the study and interpretation of such data to draw some conclusions regarding yellowing since the fines and long fibers differ not only in physical characteristics but also in chemical analysis. Perila and Roschier (*13*) found that the shorter fibers contain less alpha-cellulose, and more resins, fats, ash, and lignin than the long fibers. Since all of these components except alpha-cellulose supposedly contribute to yellowing, the long fibers should be more stable than the fines.

Table VIII. Brightness and Reversion of CEHEH Pulp on Additional Purification

	Chlorine consumed 3rd hypochlorite, %	*Original brightness, % G.E.*	*Standard* $\Delta k/s \times 10^4$
Pulp 165	..	84.0	127
Pulp 165—chlorited	..	88.0	64
Pulp 164—chlorited—hypochlorite	0.36	89.3	76
Pulp 165—chlorited—KOH extracted	..	88.9	25
Pulp 165—chlorited—KOH extd.—hypochlorite	0.33	91.7	33

The unbleached kraft pulp was fractionated with a Bauer-McNett classifier according to TAPPI Standard T 233 sm-53 with 28, 48, and 150-mesh screens in series. The percentage fibers retained was 86.3, 6.6, and 3.1 for the 28, 48, and 150-mesh screens, respectively, with 4.0% of the fibers passing through the 150-mesh screen.

In order to fractionate pulp rapidly, the standard method was modified. Screens of 28, 200, 35, and 200-mesh were placed in the Bauer-McNett classifier in that order. Twenty grams of pulp were added to both the 28 and 35-mesh compartments and the fractionator was run 10 min. at a flow rate of 3 g.p.m. filtered water before draining. The pulp retained by the two coarse screens was combined, and that retained by the two fine screens was combined. The resulting separation gave about 90% long fibers and 4.5% fines with 5% of the fibers lost to the sewer.

No chemical analyses were made on these two fractions, but it is probable that the differences, if any, were slight since on microscopic examination the fines were found to be for the most part broken or cut long fibers.

The average fiber length was determined by Graff's method (*14*) and was found to be 2.42, 2.98, and 0.72 mm. for the unfractionated fibers, the long fibers, and the fines, respectively.

Bleached pulps 120 and 130 were fractionated before the preparation of brightness handsheets. The bleaching data for these pulps are given in Table XIII. Pulp 120 was fractionated by TAPPI Standard 233 sm-53

with 28, 48, and 150-mesh screens, and pulp 130 was fractionated with 28, 200, 35, and 200-mesh screens in series. The data for the fractions from these two pulps are given in Table IX.

Table IX. Reversion and Brightness of Fiber Length Fractions

	Original brightness, % G.E.	$\Delta k/s \times 10^4$	
28 fraction of 120	84.3	116	Aged 4 hr. at 100°C., 0% R.H.
48 fraction of 120	84.0	82	
150 fraction of 120	81.9	91	
Long fraction of 130	85.2	114	Aged 1 hr. at 100°C., 0% R.H.
Fine fraction of 130	83.5	79	
Unfractionated	84.6	115	

It can be seen that the ratio of the reversion rate of the fines to that of the longer fibers is from 0.65 to 0.70. One explanation for this difference could be that the action of the bleaching agents used is different on the two fractions; since the bleaching system is heterogeneous it may be that the oxidizing power of the bleach is not divided proportionately between these two fractions. In order to study this, the unbleached pulp fractions were bleached separately. Duplicate bleaches were made on each fraction; the data for the individual bleaches are given in Table XIII. The averages of these are given in Table X.

Table X. Bleaching of Fractionated Pulp

Pulp	Fines	Longs	Unfractionated
Bleach number	158–159 average	160–161 average	162–163 average
Chlorine consumed, %			
Chlorination	5.56	5.31	5.42
1st hypochlorite	1.15	1.20	1.17
2nd hypochlorite	0.32	0.32	0.32
Total	7.02	6.83	6.91
Original brightness, % G.E.	82.9	81.7	82.0
Standard $\Delta k/s \times 10^4$	151	212	200

These data show that the fines consume slightly more chlorine during the chlorination stage, but approximately the same percentage chlorine in the first and second hypochlorite stages. It can be seen that the differences in color stability noted in the reversion of fines and long fibers bleached before fractionation continue to exist when the fibers are bleached after fractionation. In both cases the rate of reversion of the short fibers is 0.7 that of the long fibers.

The differences in the chlorine consumption of the long and short fibers are insufficient to explain the greater stability of the fines. It is believed that this greater stability is due primarily to the greater access presented by the fiber to the bleaching chemicals. In this manner the bleaching action is more uniform throughout the fiber and the removal of degradation products, both carbohydrate and ligneous, which are possible color precursors is facilitated for these short broken or cut fibers. This view is consistent with the fact that the reversion rate may be reduced by 20% by thorough washing and up to 50% by a prolonged second caustic extraction. It is important to realize that these data do not show that all fines possess greater color stability than long fibers since fines comprising 5% of the pulp passed the 200-mesh screen and were lost to the sewer. It may well be that a portion of the fines which truly differ in both morphological and chemical nature may yellow more extensively than the long fibers. Even if this is the case, however, the removal of fines to increase the color stability of a pulp would be of doubtful value since it is apparent that some of the fines are definitely *more* color stable than the unfractionated pulp. Cutting or breaking the fibers before the bleaching operation would seem to be advantageous since a higher proportion of these more stable fines would be produced in this manner. This could possibly be done either by decreasing the chip size and thus increasing the number of cut fibers, or by "beating" the pulp before bleaching.

The Effect of Additives on Reversion

Introduction. The study of reversion by the introduction of materials into the sheet has for the most part been aimed at the commercial application of certain compounds to increase color stability. The detrimental effect of additives is also of interest, particularly if the additive used normally occurs in bleached pulp such as calcium salts, iron, and resins.

The additives investigated in this study were iron and Versene, the first for possible detrimental effect and the latter for possible beneficial effect.

Iron. Iron has often been considered to promote brightness reversion by catalyzing oxidation. In order to study the relationship of this constituent to reversion, a series of pulps of varying iron content were prepared.

An attempt was made to prepare an iron-free control sample of bleached pulp with a dilute hydrochloric acid wash. This method has been used by McLean to remove all ash except silica from samples of unbleached kraft pulp (*15*). Pulp 165 was soaked 45 min. in 0.1 *N* HCl, washed thoroughly, soaked overnight in distilled water, and washed several times again before forming brightness handsheets. Pulp 180 was given the same general washing sequence; one sample was soaked in 0.1 *N* HCl for $11^1/_2$ hr. The iron contents of both pulps 165 and 180 were approximately halved while the total ash was reduced only slightly for the former pulp but markedly for the latter. It can be seen in Table XI

Table XI. Ash Removal with Dilute Hydrochloric Acid

Pulp designation	*Treatment*	*Ash, %*	*Fe, p.p.m.*	*Original brightness, % G.E.*	*Standard* $\Delta k/s \times 10^4$
165	None (control)	0.17	27	83.7	130
165	Soaked 45 min. in 0.1 *N* HCl	0.14	16	83.5	128
180	None (control)	0.15	15	85.4	101
180	Soaked $11^1/_2$ hr. in 0.1 *N* HCl	0.04	7	86.4	119

that in no instance did ash removal increase color stability. The brightness increase obtained by soaking pulp 180 in hydrochloric acid was completely offset by the subsequent increase in the reversion rate; at the conclusion of the standard 2-hr. aging interval the con-

trol and acid-washed sheets had brightness values of 80.9, 81.1, and 80.9, respectively.

The pulp samples of varying iron content were prepared in accordance with the findings of Keller and Simmonds (*16*) that iron is more strongly adsorbed under neutral or alkaline conditions and that more iron is adsorbed as the iron concentration of the soaking water is increased. Eight-gram samples of pulp 170-C were soaked $^1/_2$ hr. in 2 liters distilled water containing known quantities of ferric ammonium sulphate at pH 7. The pulps were then washed, made into brightness sheets, and aged under standard conditions. The amount of iron present in the ash of the aged sheets was determined by the colorimetric thiocyanate method (*17*). The data for these pulps are presented in Table XII.

Table XII. Effect of High Iron Content on Pulp Reversion

Sample no.	*Fe^{+++} in soaking water, p.p.m.*	*Fe^{+++} in pulp, p.p.m.*	*Original brightness, % G.E.*	*Standard* $\Delta k/s \times 10^4$
1	0	20	84.1	135
2	0.05	22	84.0	127
3	0.15[a]	17	84.1	135
4	0.80	39	82.2	151
5	1.50	81	79.3	175
6	3.00	127	74.1	200

[a] Mill process water for the production of bleached pulp usually contains <0.15 p.p.m. Fe.

The added iron lowered the original brightness of the pulp to an extent proportional to the quantity of iron present. The increase in *k/s before* aging due to the iron added was approximately 0.0023 unit for each part per million iron added. Not only did the iron lower the original brightness, but it also increased the subsequent accelerated reversion rate. It can be seen that the reversion rate is increased by about 50% as the iron content is increased from 20 to 127 p.p.m. This increase may be due to both catalytic acceleration of the reversion reactions and to color intensification by the formation of iron salts or complexes of the organic colored materials which originated either with or without iron catalysis. Color formation and intensification is observed when iron salts, such as ferric chloride, are added to many phenols and similar compounds.

Versene. An attempt was made to remove the ash constituents, including iron, of bleached pulp by treatment with Versene, the sodium salt of ethylenediamine tetraacetic acid. This compound forms complexes with metallic ions, thereby rendering them inactive; it will dissolve water-insoluble salts, e.g., calcium oxalate, by exchanging its sodium ions for the metallic ions of the insoluble salt. Thus, this compound could be effective in lowering the yellowing rate of pulp by removing or complexing ash constituents which could possibly catalyze reversion and also contribute to the alkalinity of the sheet.

Eight-gram samples of pulp 165 were soaked overnight at 0.2% consistency at 7.0 pH and at 10.8 pH with 0.82 gram Versene Fe-3 added. The samples were washed thoroughly the following day before preparing brightness handsheets and aging.

The original ash content, 0.17%, and the original iron content, 27 p.p.m., were reduced to 0.15% and 15 p.p.m., respectively. No increase in brightness stability was obtained. However, the original brightness, 83.7%, was increased to 84.9% by the Versene treatment. It is probable that the detergent qualities of the Versene were responsible for this increase since Dixson (*18*) has shown that wetting out agents may decrease fiber bonding thus increasing the scattering coefficient and consequently increasing the reflectivity of the sheet.

Table XIII. Data for Experimental Bleaches

Bleach designation	*Chlorination*	*First hypochlorite*	*Second hypochlorite*	*Total*	*Original brightness, % G.E.*	*Points brightness drop during standard aging*	*Standard* $\Delta k/s \times 10^4$
120	5.74	1.23	0.27	7.24	84.2	4.0	96
130	5.51	1.37	0.28	7.16	84.6	6.5	168
137	6.21	0.28	0.21	6.70	82.3	5.0	143
138	6.21	0.28	0.21	6.70	82.6	5.2	153
139	6.21	0.28	0.22	6.71	82.6	5.3	150
140	6.21	0.28	0.23	6.72	83.3	5.7	156
141	6.21	0.28	0.24	6.73	83.2	5.8	160
142	6.21	0.28	0.25	6.74	83.7	6.1	164
143	6.21	0.28	0.25	6.74	83.2	5.9	163
144	6.21	0.28	0.24	6.73	82.9	6.1	174
145	6.21	0.28	0.22	6.71	82.6	6.3	185
147	5.57	1.16	0.31	7.04	80.7	4.9 to 5.7	155 to 186
148	6.00	1.26	0.24	7.50	80.8	6.3 to 6.9	208 to 245
169	5.17	1.15	0.24	6.56	76.9 to 79.0	4.7 to 6.4	165 to 246
170-A	5.33	1.45	0.36	7.14	81.3	4.9	149
170-B	5.33	1.45	0.32	7.10	83.6	3.9	97
170-C	5.33	1.45	0.33	7.11	83.7	3.4	83
180	5.42	1.36	0.21	6.99	85.2	4.2	94

SUMMARY AND CONCLUSIONS

An investigation was made of the yellowing brought about by the heating of bleached kraft pulps. Pulps prepared from a single unbleached slash pine kraft pulp were used with a bleaching sequence consisting of chlorination, caustic extraction, calcium hypochlorite oxidation. The conditions maintained during these bleaches closely paralleled those used commercially.

The reproducibility of the bleaching techniques used was determined in order to establish the validity of all conclusions and comparisons. It was found that the brightness values agree within 0.5% G.E. and that the

standard $\Delta k/s$ values agree within 10% of the total numerical value.

After the precision of both brightness and reversion data was established, the effects of several bleaching variables on these properties were determined. The pH maintained during hypochlorite oxidation, the duration of the second caustic extraction, and the washing of newly bleached pulp were studied. Of these factors, a thorough caustic extraction has the greatest effect in reducing reversion. Omission of the second caustic extraction can increase reversion by 50%. Thorough washing and the maintenance of high pH during the hypochlorite stages can each reduce reversion by 20%. The process variables of caustic extraction and the pH of hypochlorite oxidation can easily be adjusted in industrial operations for the attainment of high color stability, but only by relatively long diffusion periods could commercial washing be changed to increase color stability.

A comparison was made of the reversion characteristics of long and short fibers of pulps fractionated both before and after bleaching. It was found that the reversion rate of the short fibers, or fines, was only 0.7 that of the long fibers. The greater color stability which was found for the shorter fibers can be attributed to the more rapid diffusion of materials from within the fibers during the course of the bleaching stages.

Iron and Versene were individually added to the pulp before accelerated aging tests; the former was used for its possible detrimental effect and the latter for possible benefits in increased color stability. The presence of iron was shown to definitely increase brightness reversion, but no decrease of reversion was realized by the addition of Versene. The addition of Versene did, however, increase the original brightness slightly.

It was found that the measurement of the relative reversion rates of pulps within a given type (e.g., slash pine kraft pulp bleached by a five-stage procedure) can be successfully carried out under widely varying temperature conditions at a fixed temperature.

A pulp highly purified by acidified sodium chlorite bleaching and caustic extraction was given a subsequent relatively drastic calcium hypochlorite bleach. This calcium hypochlorite treatment decreased the color stability only slightly.

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The Simultaneous Burning of Bark and Coal

HAROLD HANSEN and L. P. COPIAN

Faced with the requirement for additional steam capacity, the Champion Paper & Fibre Co. of Canton, N. C., decided that a new steam generating unit, firing bark and coal was needed. Studies of existing methods for efficient utilization of bark were made and based on these studies and the company's extensive experience with bark burning. It was decided to install a spreader stoker-fired boiler of the two-drum, single-pass, baffleless design. The unit has a water-cooled furnace, superheater, heat recovery equipment, and dust collector. Nominal rating is 200,000 lb. steam per hr. at 425 p.s.i.g. and 750°F. The installation is designed to burn unhogged bark and coal in combination or alone. The bark is distributed in the furnace by pneumatic distributors, and coal is distributed by mechanical feeders. The spreader stoker traveling grate is of the rear ash discharge type. There is no bark storage, since the unhogged bark is fired directly as received from the drum barkers. Coal is used to supplement the bark and also to even out the steam flow. The control system is arranged so that the unit fires all the bark it receives and at the same time maintains any set minimum loading by burning coal at the required rate. The plant steam pressure is maintained by one of the other boilers in the plant. The excellent performance of the unit is evidenced by the data collected over a typical, 5-day, 24-hr. period. Bark evaporation rates (pounds steam per pound bark) are in the order of 3.5. Grate refuse combustible runs in the order of 1.5%.

HAROLD HANSEN, Asst. Supt., Power Dept., The Champion Paper & Fibre Co., Canton, N. C., and L. P. COPIAN, Service Engineer, Riley Stoker Corp., Worcester, Mass.

THE Champion Paper & Fibre Co. of Canton, N. C., has used bark and woodroom refuse as boiler fuel for over 45 years. As recently as 1951 about 25% of the total steam requirements of the mill was supplied by black liquor recovery units, 10% by wood fuel, and the balance by three pulverized coal-fired boilers. However, steam requirements had increased and indications were that further increases would be needed to a point where

no standby capacity would be available for the winter months. Also indicated was an increase in the available amount of bark for fuel. As a result, Champion decided to investigate the economics of installing a modern boiler which could provide the necessary steam from the available bark and also provide standby steam capacity.

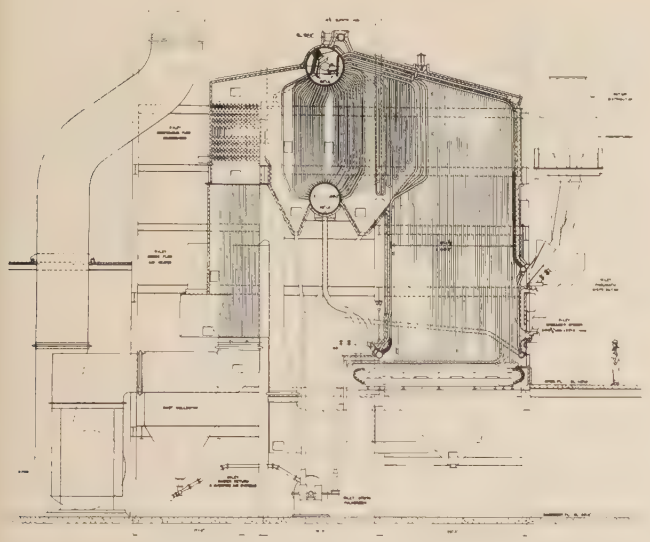


Fig. 1. General arrangement of steam generator

The decision would be based upon Champion's years of wood and bark burning experience. The initial furnace installation was of the cell type, having a large amount of refractory surface as was common practice at the beginning of the century. There were three of these cells on each side of a 300-hp. two-drum, single-pass, Edgar water tube boiler. Flat grates were used, and the products of combustion entered the tube bank at one end. The cell design was later replaced by a single Dutch oven furnace on each side of the boiler.

When a 600-hp. pulverized coal-fired boiler was no longer needed to burn coal it was adapted to burn bark and wood refuse. It was equipped with a rectangular refractory furnance and a suspended arch roof. Air for combustion was admitted through five, 6-in. blow pipes that were inserted in the front wall about 3 ft. above the refractory hearth. Steam generating efficiency was doubled on this unit from that on the Dutch oven Edgar boilers.

Later when the amount of fuel from the woodrooms was considerably increased, four existing 800-hp. Sterling boilers, equipped with multiple retort underfeed stokers, were placed into service. These boilers are in batteries of two facing a common firing aisle. A revolving chute, designed and built at the plant, received the bark delivered by a belt conveyor from the drum barkers. This revolving chute discharged the fuel to a cylindrical opening below. This opening was divided into quarters by metal partitions. Each of these quarter sections was connected to steel plate chutes that delivered the fuel to an opening in the front wall of the furnace. The furnace front wall at the entrance of the chute was redesigned. Protection for the chute from furnace heat was provided by a refractory pier and a cast iron curtain protected by 9 in. of refractory. This curtain was used to deflect the bark flow down into a pile at the front wall, covering the greater part of the underfeed section of the stoker. Although some burning took place over the underfeed section, the greater part took place on the overfeed section, the dumps, and along the high, side wall tuyères. Efficiencies of better than 60% were obtained. Capacities, however, were limited, because carryover and stack emission became troublesome when rated output was exceeded. In all the foregoing cases the fuel was burned in piles and steam was generated at 125 p.s.i.g. All other steam generating equipment was at 400 p.s.i.g.

All wood used by the pulp mill is delivered by truck or railroad cars and is barked in drum barkers. Both pine and hardwoods are used in about 3 to 1 ratio. In order to determine the amount of bark available, in 1949 all the bark from measured wood used by the woodrooms for a 24-hr. period, was sheared from a belt conveyor into railroad gondolas. The time required to fill each gondola was recorded, and the gondola was then weighed on a railroad track scale before it was shifted to a siding. Here a locomotive crane unloaded the contents into a bin. The bark was then raked to a conveyor and transported to the boiler house for burning.

FUEL BURNING PROBLEMS

From the information available at that time it was decided that a spreader stoker would be far superior to the Dutch oven for burning bark; and would have the added advantage of easy adaptability for burning coal as an auxiliary fuel. All known installations of wood burning spreader stokers incorporated hogs to prepare the fuel to the proper size; also, a storage bin served as a feeder supplying fuel to the furnace.

In January, 1951, specifications for a spreader stoker fired steam generating unit were submitted to equipment manufacturers for bids. The size of the unit, when burning coal, was determined by the future steam demands. The size required for coal burning, however, was greater than that required to burn the bark. A

Fig. 2 Bark conveyor

moderate sized bin to even out variations in bark flow was specified. A dust collector was included to eliminate objectionable stack discharge.

A question arose when information on the cost of the storage bin, feeders, and wood hog equipment was received: why have all this equipment?

To answer this question it was necessary to investigate what the effect of particle size on burning would be when using a spreader stoker with a traveling grate. First knowledge of the sizing of the fuel as it came from the drum barkers was needed. Accordingly, samples of varying weight were sheared from the fuel belt, screened with hand screens, and the various parts weighed. Table I shows the results. The fact that a considerable part was large size was at first thought to be detrimental. However, it was soon determined that the oversized pieces would positively be burned because of the high furnace temperature and the available supply of oxygen for the several hours required for the grate to carry them to the ash pit. Elimination of the fuel storage and hogging equipment would result in a substantial saving of capital expediture and avoid the high maintenance cost of wood hogs when subjected to a normal amount of scrap iron, stones, and other foreign material.

Equipment manufacturers were requested to submit new bids covering the burning of unhogged fuel, without storage. The specified capacity of the unit was increased by 10% to take care of the 1-hr. peak flow of 90,000 lb. of 46% moisture bark that calculations based on previous weighing indicated.

The burning of unhogged wood fuel was a departure from previous practice by manufacturers of spreader stokers. In the past the customer or the manufacturer had procured the wood feeders from other manufacturers and the problem of bridging of fuel over the feeders had never been solved.

In many places in the Pacific Northwest, wood is a primary fuel. Here were inspected installations of both spreader stokers and Dutch ovens. In performance the superiority of the former was not questioned.

At Prince Rupert, B. C., a stoppage at a conveyor opening caused irregular feed to the distributors. This created a pile of wet bark 3 ft. high and 6 ft. long to accumulate on the grate opposite one of the distributor openings. This pile was completely burned out in a

Fig. 3. External view of bark proportioner

half hour. At a spreader stoker installation in Eugene, Ore., the attendants speeded up one of the feeders purposely creating a pile of wood fuel 3 ft. deep on the grate. Again the pile burned out in less than an hour. The complete burning of these piles on the spreader stoker grate indicated that sizing of bark and wood fuels is not necessary for spreader stoker burning. Sizing of bark and wood fuel, if needed, would only be to meet the requirements of conveyors, storage bins, and feeders. As a protective measure, space in the design was provided so that hogs and storage could be installed later, if necessary.

DESCRIPTION OF NEW UNIT

The steam generator is of the two-drum, single-pass,

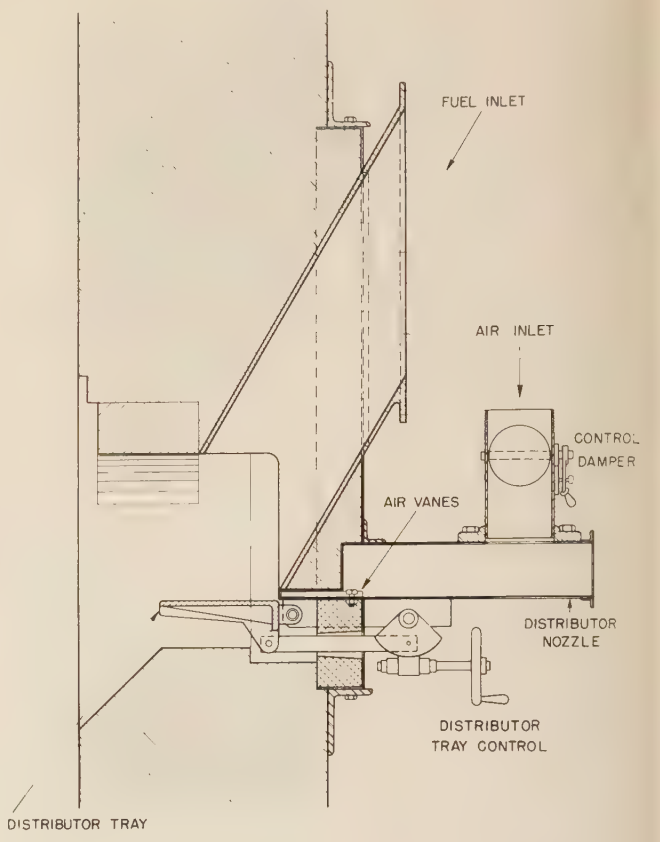


Fig. 4A. Arrangement of bark distributor

baffleless design equipped with water-cooled furnace, radiation-convection superheater, continuous tube economizer, cross-flow air heater, and a dust collector. The furnace is 24 ft. 9 in. wide by 17 ft. deep. The height from grate surface to the roof is 38 ft. There are no soot blowers installed, although wall boxes were provided. The arrangement of this equipment is shown in Fig. 1, and the general performance data are given in Table IIA.

The force draft fan is powered by a 250-h.p., 1200-r.p.m., constant speed motor, and volume is controlled with inlet vanes. The induced draft fan is powered by an 800-h.p. turbine through a speed reducer unit. Auxiliary air requirements for overfire air turbulence, bark distribution, and cinder reinjection are supplied by an auxiliary fan receiving air from the air heater outlet air duct.

The wood fuel handling system is integrated as much as possible with existing facilities. Bark, stripped from pulpwood logs in drum barkers, is brought to the bark proportioner by a system of belt conveyors (Fig. 2). The proportioner consists of a rotating distributor which receives the bark as it is discharged from the last conveyor belt and consecutively directs the bark flow down six separate chutes. For additional flexibility the rotat-

ing distributor is driven through a variable speed reducer by a 3-h.p., 1160-r.p.m. electric motor. The speed can be varied from 4 to 14 r.p.m.; however, once the optimum speed is determined, it needs no further regulation. Figure 3 is a view of the bark proportioner. The six chutes which receive the bark lead down to the pneumatic distributors located in the furnace front wall. These spread the bark in the furnace by means of a

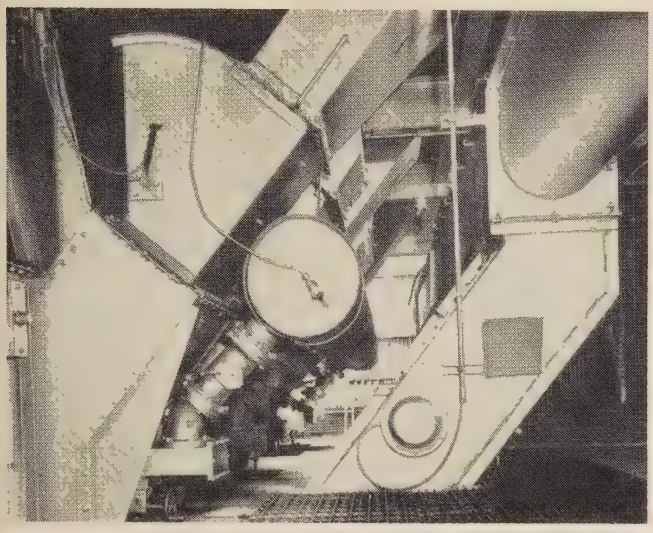


Fig. 4B. General view of bark distributor

blast of preheated air. The bark distributors are located approximately 11 ft. above the grate surface, thus affording ample time and space for the drying and suspension burning of the bark which is aided by the blast of hot distribution air. A view of these distributors is shown in Figs. 4A and 4B.

Coal is supplied from an existing bunker and passed by a system of screw conveyors through automatic coal scales to the six coal feeders located in the furnace front wall. The feeders are located approximately 4 ft. above the grate, which is normal setting for a spreader stoker installation burning coal. See Figs. 5A and 5B for a general view of the feeders.

The grate is of the rear ash discharge type, fully zoned to properly proportion air to the required areas. The rear ash discharge type was chosen in order to have sufficient grate retention time to permit extra large pieces of wood refuse to be burned before being discharged to the ash pit. These large pieces of wood refuse may be as much as 3 in. in diameter and as long as 3 ft.

Overfire air turbulence is provided by a system of 2-in. diameter air jets, located in the furnace rear wall and 3/4-in. diameter jets located beneath each coal feeder. The rear jets, which produce most of the furnace turbulence, are placed 30 in. above the grate surface in order to penetrate and promote turbulence in the zone of highest flame temperatures.

The cinder return system is designed for complete reinjection of fly ash trapped in the boiler hoppers and dust collector. Fly ash resulting from burning bark can be high in combustible content and comparatively large in size. On an experimental basis and as a possible refinement, a standard coal pulverizer is used to grind fly ash and discharge it to the furnace through nozzles in the rear wall. Fly ash, fed to the pulverizer, includes all the refuse from the boiler hoppers and one third of the refuse from the dust collectors. The remaining two-thirds of the dust collector refuse bypasses the pulverizer and is reinjected directly to the furnance.

COMBUSTION CONTROLS

Figure 6 is a general view of the boiler control panel. The control system design is based on the requirements that the bark must be burned directly, since it is received at a fluctuating rate and coal must be burned to supplement the bark when bark flow drops below a set minimum level or stops completely. This method insures against loss of ignition during periods of no bark flow and is used to supplement plant steam capacity. Since the unit must burn whatever bark it receives, header steam pressure cannot be used as a controlling element. The black liquor boilers mentioned earlier are in a similar independent situation—burning black liquor as required. Therefore, the function of maintaining plant steam pressure is assigned to the largest of the three pulverized coal-fired boilers, the only one equipped for automatic control; the other two being base loaded.

To obtain this type of control action, the last section of bark conveyor, the section that discharges to the proportioner, has a calibrated weight integrator and scale installed beneath the conveying belt surface. This sends an impulse to the forced draft fan control system through a corrector regulator that corrects air flow to steam flow. Air flow measurement is taken at a venturi duct section between the air heater outlet and windbox.

The coal feed rate is established by a splitter relay which balances steam flow and coal feed rate against the minimum load setting.

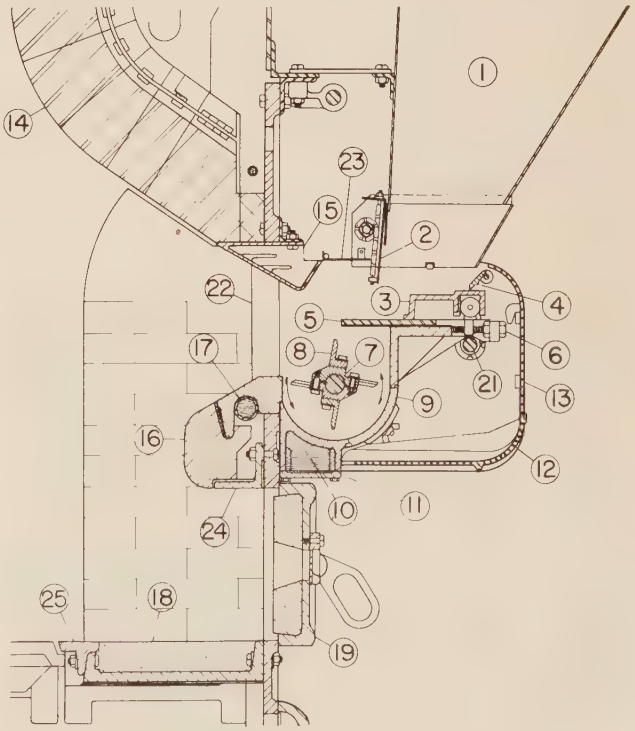


Fig. 5A. Arrangement of coal spreaders

Fuel-air ratio, coal feed bias, and forced draft air bias controls are also incorporated into the system to meet any change in fuel or air requirements.

Boiler feedwater control is of the two-element type, receiving impulse from drum water level and steam flow. Remote manual control of the feedwater flow is

provided at the control panel. The feedwater is taken from a main boiler feedwater supply line, eliminating the need for separate pumps for this unit.

An oxygen indicator and recorder gives the operator a visual indication of furnace performance. (Fig. 7C).

The induced draft fan controller gets its impulse from furnace draft. Controls were provided on the I.D. fan inlet dampers and the I.D. fan turbine governor. However, after trying various combinations of controlling, it was found that satisfactory performance for these particular load conditions was obtained by locking open the I.D. fan inlet dampers and letting fan speed maintain the required furnace draft.

OPERATION

Figure 7A shows the bark flow rate chart for a typical 24-hr. period of operation. The rate is extremely erratic, and several times the bark flow is stopped entirely.

Table I shows typical size analyses of ten random bark samples from pine and hardwoods.

Table I. Bark Size Consist Analyses

Sample no.	*Weight of sample, lb.*	*Retained on 3½ by 4-in. screen* Lb.	%	*Retained on 1½-in. screen* Lb.	%	*Passed through 1½-in. screen* Lb.	%
1	281	35	12.5	97	34.5	149	53.0
2	170	25	14.7	60	35.3	85	50.0
3	86	13	15.1	26	30.2	47	54.7
4	118	27	23.0	41	34.5	50	42.5
5	198	46	23.5	58	29.1	94	47.4
6	96	16	17.3	34	35.1	45	47.6
7	154	42	27.6	46	29.5	66	42.9
8	175	41	23.4	55	31.1	80	45.5
9	108	18	16.7	37	34.4	53	48.9
10	134	17	12.7	45	33.2	72	54.1
Totals	1521	280	18.5	499	32.7	742	48.8

Notes: Sample no. 1—This sample contained two sticks 4 by 18 in. and one long slab of hardwood bark on the 3½-in. screen. Sample no. 2—Sample was fairly uniform with nothing large. Sample no. 3—Sample was unusually stringy. Sample no. 4—Unusual amount of large pieces of bark from jack pine approximately 4 by 12 in. Sample no. 7—All oak bark, some measuring 4 by 12 in. Many strings.

All material retained on the 3½ by 4-in. screen was mostly strings from inner bark, unless otherwise noted. Also, bark analyzed was jack pine bark, unless otherwise noted.

The bark sizing and the chemical analysis, shown in Table IIB, are the basis of design of the unit. There are periods when the bark is laden with stones and miscellaneous refuse which cause no difficulty to operation since there is nothing in the bark handling system that can be damaged by them.

The proportioner, which feeds the bark to the pneumatic distributors, handles all the flow rates and sizes of bark with ease. A speed of 10 r.p.m. was found to give good results in feed. The bark chutes are attached to the proportioner in such an order as to feed bark to the six pneumatic distributors in a 1-4-2-5-3-6 sequence.

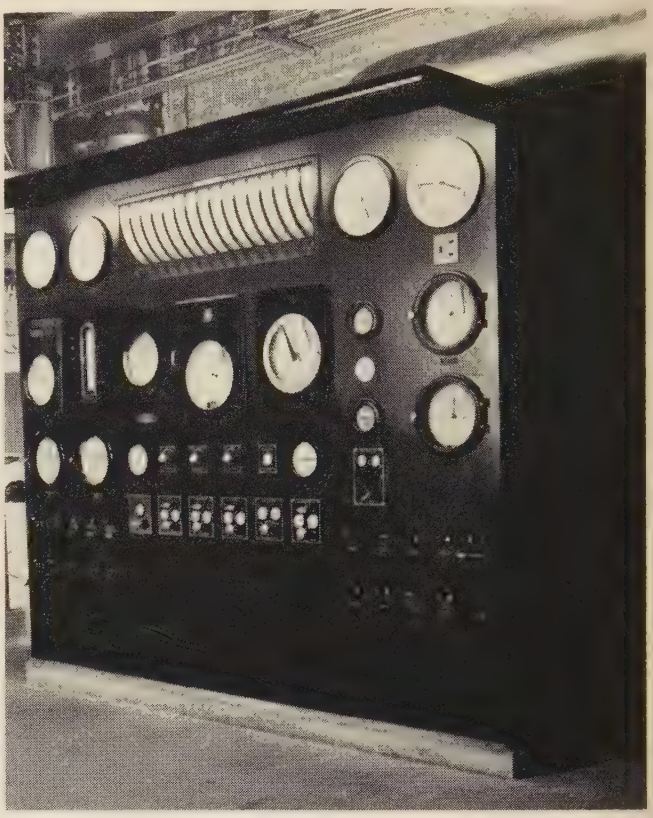


Fig. 6. General view of boiler control panel

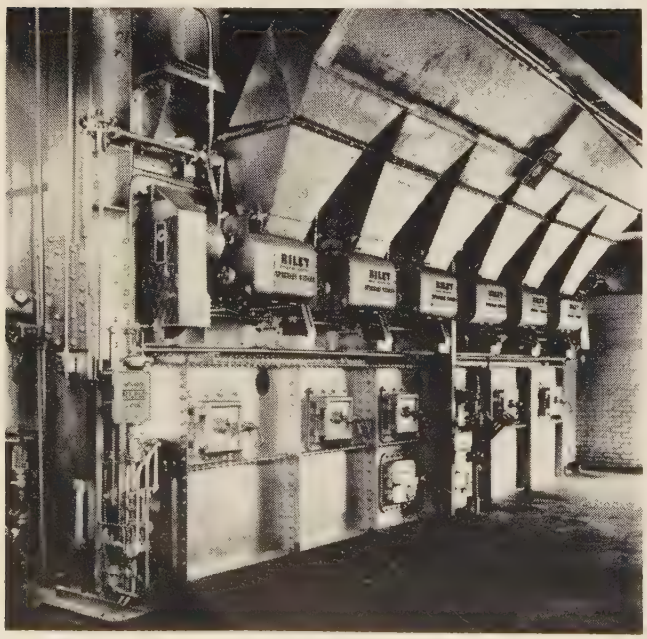


Fig. 5B. General view of coal spreaders

Table II. Design Data

	Bark	*Coal*
A—General Performance Data		
Steam flow, lb./hr.	200,000 cont.	230,000 cont.
Steam flow, lb./hr.	268,000 1 hr.	250,000 4 hr.
Steam pressure, p.s.i.g.	425	430
Steam temperature, °F.	750	720
Feed water temperature into economizer, °F.	330	330
Forced draft air and auxiliary air temperature, °F.	400	370
B—Bark Analysis		
Moisture	45.9%	
Ash	0.4	
Carbon	28.3	
Oxygen	22.1	
Hydrogen	3.3	
B.t.u. as fired	4730	
C—Coal Analysis		
Moisture		5.3
Volatile matter		32.0
Fixed carbon		52.1
Ash		10.6
Ash fusion temperature		2300°F.
B.t.u. as fired		12,500

Table III. Operating Data for 5-Day Period on 24-Hr. Basis

Steam output, lb./day		Coal input, tons/day	Bark input, tons/day	Bark evap. rate, 16 steam/ lb. bark	Bark analysis		Coal analysis		Ashpit refuse, % combustion
From coal	From bark				B.t.u. as fired	Moisture, %	B.t.u. as fired	Moisture, %	
1,656,000	3,242,000	82.8	483	3.4	5080	40.9	13,000	5.0	1.55
1,494,000	3,688,000	74.7	531	3.5	5070	39.8	13,000	3.5	1.25
1,899,000	3,414,000	94.9	505	3.4	4860	41.6	13,400	3.5	1.20
1,917,000	3,177,000	95.9	442	3.6	5230	39.2	13,000	5.5	1.52
1,578,000	3,781,000	78.9	513	3.7	5100	40.1	11,600	9.0	1.24

Note: Boiler operating with approximately 3% continuous blowdown.

The arrangement provides balanced bark distribution and furnace flame conditions.

The coal supply is an Eastern Kentucky strip mine product having an analysis as shown in Table IIC.

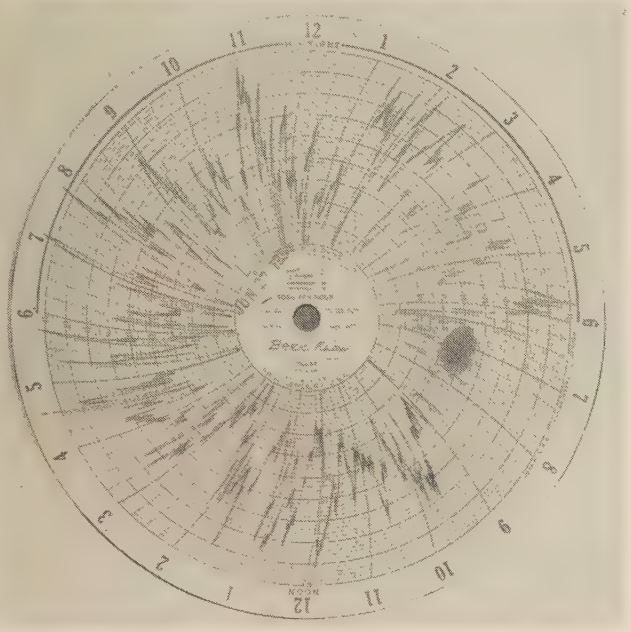


Fig. 7A. Typical daily flow chart—bark flow

Since the operation of the unit, when firing coal only, is typical of spreader stoker performance, it will not be discussed here at length, and comment will be confined to firing coal in combination with bark only.

Flame placement in the furnace, when firing wood alone, is toward the rear wall; flame placement, firing coal alone, is toward the front wall. The two fuels in combination, result in even flame distribution from front to rear. This flame is turbulent because of the front and rear overfire air jets, thus minimizing smoke and fly ash carryover. Another factor favoring low fly ash carryover is the unhogged sizing of the bark. The large pieces are heavier and have less tendency to be carried out of the furnace.

The grates are driven by hydraulic units which give close speed regulation in the range from 0 to 13 ft. per hr. For the load settings described below, a speed of approximately 3 ft. per hr. results in an ash discharge thickness of from 4 to 6 in. This heavy ash bed is desirable on spreader stokers from the standpoint of operation and results in improved grate longevity. Figure 8 shows the grate refuse as it is being discharged to the pit. It is loose and friable, regardless of the proportion of the two fuels. The ashpit refuse analysis (Table III) shows that the per cent combustible is extremely low, resulting in a negligible carbon loss to the ash pit.

The overfire air turbulence system is equipped with an automatic control system to vary air pressure with load. However, with a minimum load setting of 200,000 lb. per hr. on the boiler, it has been found satisfactory to maintain the rear overfire air pressure at 16 in. (water gage) regardless of any peak steam flow above the 200,000 lb. per hr. minimum. Front overfire air

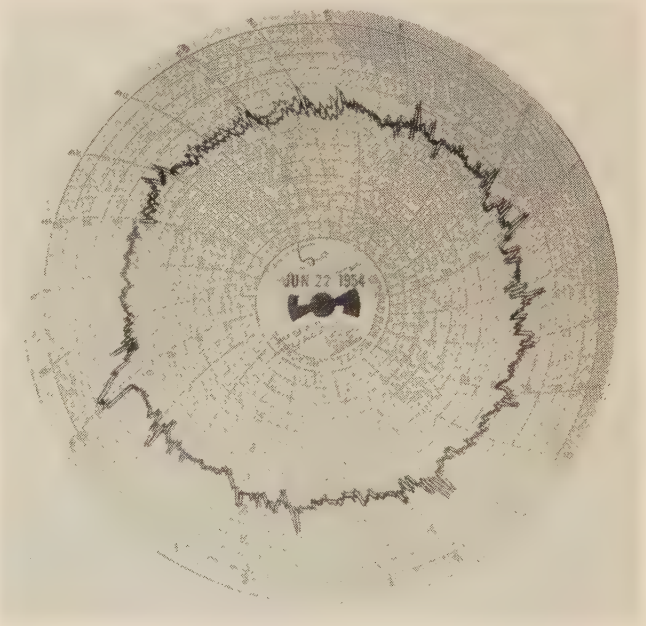


Fig. 7B. Typical daily flow chart—steam flow—air flow

operates at the same 16 in. pressure, while the pneumatic distributors operate at 20 in. regardless of bark flow rates. Adjustment is available from the control panel for these systems; any necessary changes are at the discretion of the operator. Under normal conditions no changes are required.

The boiler hopper cinders are gravity fed to the pulverizer. The dust collector cinder reinjection system operates at 16-in. air header pressure. The reinjected fly ash is introduced into the furnace through the rear wall at a level approximately 30 in. above the grate surface and into a zone of extremely high temperature which is necessary for reigniting the fly ash carbon.

Although soot blower wall boxes are provided in the boiler setting, no blowers have been installed. Inspection of slag screen, superheater, boiler, and recovery surfaces has shown them to be free from all deposits and accumulations.

The increased mass-flow of furnace gases when firing wood versus coal results in higher steam, feedwater, preheated air, and air heater outlet gas temperatures. However, the maximum difference in temperatures fall

within a narrow band of approximately 30°F. when burning wood and coal together in various proportions.

The automatic control system regulates the forced draft air and coal feed in accordance with bark and steam flow. The steam flow-air flow chart (Fig. 7B) is typical of performance under automatic control. The boiler and controls are quickly responsive in maintaining minimum load on coal when bark flow drops off; and are also quickly responsive to steam flow increase when heavy bark flow rate provides B.t.u. input above the minimum load setting.

This minimum load has been set for 200,000 lb. of steam per hr. to meet mill requirements. At 200,000 lb. the steam is produced from variable proportions of bark and coal, while above 200,000 lb., all the coal is off and the steam is produced from bark alone. This minimum steam flow dampens out the load swings which the variations in bark flow would impose and, at the same time, provides for the plant's increased steam requirements.

DISCUSSION

Evaporation figures (steam per pound of bark) were better than anticipated. Table III shows the operating data for five consecutive 24-hr. periods. The evaporation rates when firing bark are derived by assigning a 10-lb. test evaporation rate to coal and substracting the steam produced from coal from the total steam generated. Frequent checks have demonstrated that coal scales, coal car weights, and bark weights are all within the limits of accuracy.

With the control arrangement used, a given steam flow and fuel-air ratio will result in a constant amount of forced draft air input, regardless of the variable proportions of bark-to-coal being burned. Figure 7C

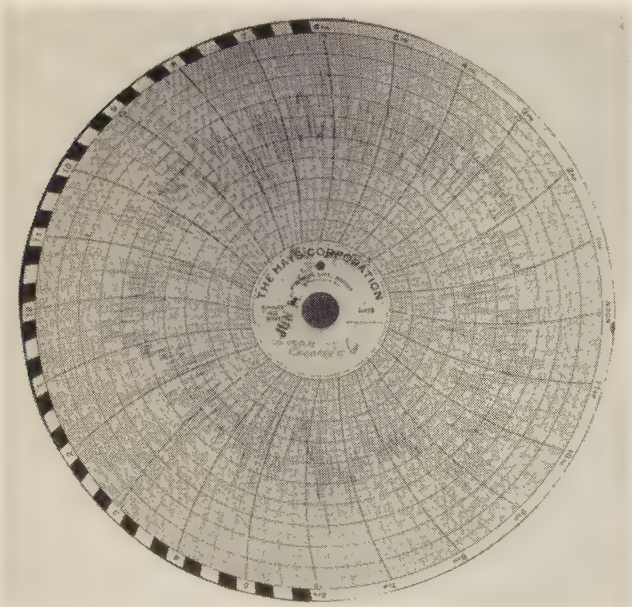


Fig. 7C. Typical daily flow chart—oxygen recorder

shows the oxygen recorder chart for a 24-hr. period. The per cent oxygen in the dust collector outlet flue gases varies from a minimum of 3% to a maximum of 7%, the lower percentage occurring at high bark flow rates and the higher percentage occurring at high coal rates. The normal range of oxygen percentage varies within the limits of good performance without requiring further automatic controlling action, however, manual adjustment is available if necessary.

A factor to be weighed against performance is the labor required to obtain good operation. The new steam generating unit is in the building adjacent to the

Fig. 8. View of grate refuse being discharged to ashpit

four old bark burners but is isolated from the rest of the steam plant. Two men per shift have been found to be adequate operating personnel for this new unit. A general shift foreman supervises all steam and power generation for the plant.

The unit has not operated long enough to give reliable maintenance information. However, there is no reason to expect anything but normal maintenance, especially since the major maintenance items of hogging, storage, and feeding equipment have been eliminated. The availability of the unit will be contingent on the maintenance required.

CONCLUSION

Engineering and design of this unit were accomplished by the purchaser's personnel working in collaboration with the contractor's engineering department.

Individually, there are certain practices in the field of bark burning which are of common usage. The major innovation of this installation is the inclusion of several of the more desirable of these features into the design of a modern bark burning spreader stoker installation. Chiefly, these features are: the firing of bark without any form of benefication, the firing of bark directly as it is received from the barking drums without any storage, the firing of bark and coal singly or in combination of various proportions, and operating the unit by application of automatic controls.

The excellent design and performance of this unit give to the pulp and paper industries, and others having problems in wood refuse burning, an installation which advances the technique of burning this type of fuel.

Received Dec. 23, 1954. Presented at the Ninth Engineering Conference of the Technical Association of the Pulp and Paper Industry, Philadelphia, Pa., Oct. 18-20, 1954.

ASSOCIATION NEWS AND EVENTS

Local Section Meetings

Pacific: Nov. 15, 1955, Longview, Wash., "Routine Control Methods"; Jan. 10, 1956, Everett, Wash., Engineering Program; March 2, 1956, Camas, Wash., Shibley Award Program; May 17–19, 1956, Gearhart, Ore., Annual Meeting, Joint Meeting with Pacific Division, APPMS Association.

New England: Dec. 9, 1955, Roger Smith Hotel, Holyoke, Mass.; April 6, 1956, Roger Smith Hotel, Holyoke, Mass.; June 8–9, 1956, Oceanside Hotel, Magnolia, Mass.

Southeastern: Nov. 18–19, 1955, Hotel Dempsey, Macon, Ga.; Jan. 20–21, 1956, Francis Marion Hotel, Charleston, S.C.; March 23–24, 1956, Roosevelt Hotel, Jacksonville, Fla.; May 18–19, 1956, King & Prince Hotel, Brunswick, Ga.

Lake Erie: Nov. 18, 1955, Hotel Carter, Cleveland, Ohio, "Quality Control and Testing," visit to plant of Thomson Products Co.; Jan. 20, 1956, Hotel Carter, Cleveland, Ohio, "Printing Equipment," visit to the Harris Press; March 23, 1956, Steubenville, Ohio, "Production and Process Control," visits to local paper mills; May 18, 1956, Cleveland, Ohio, Annual Meeting.

Empire State Central District: All meetings held at the University Club, Syracuse, N.Y.; November 4, 1955, "Automatic Steam Generation"; Dec. 2, 1955, "Mill Sanitation," by Ralph Russell, Syracuse University; Jan. 6, 1956, "Methods of Coloring Paper," by Maurice Landberge General Dyestuff Corp., New York, N.Y.; Feb. 3, 1956, "Paper Machinery Developments"; March 2, 1956, "Converting Paper with Plastics"; April 6, 1956, "Papermaking in Europe," by Robert F. Vokes, Dilts Machine Works, Fulton, N. Y.

Empire State Western District: Nov. 2, 1955; Dec. 7, 1955; Feb. 1, 1956; April 4, 1956; May 2, 1956.

Maine-New Hampshire: Oct. 28–29, 1955, Lafayette Hotel, Portland, Me.

Lake States: Nov. 8, 1955, Wausau Club, Wausau, Wis., afternoon visits to mills of Mosinee Paper Mills, Mosinee, Wis., and Marathon Corp., Rothschild, Wis., panel discussion on "Wet Strength," H. C. Crandall, Mosinee Paper Mills, Moderator; Jan. 10, 1956, Northland Hotel, Green Bay, Wis., "Sulphite Spent Liquor Utilization"; March 13, 1956, Hotel Conway, Appleton, Wis., C. J. West Award Program; April 10, 1956, Beloit, Wis., afternoon visit to plant of Beloit Iron Works, engineering program; and May 8, 1956, Annual Meeting.

Ohio: Nov. 7, 1955, Hotel Manchester, Middletown, Ohio, "Management," by Charles Kluss, Champion Paper & Fibre Co., Hamilton, Ohio, joint meeting with Miami Valley Superintendents; Dec. 13, 1955, Legion Hall, Middletown, Ohio, "Printing," by F. A. Weymouth, Printing Ink Division, Interchemical Corp., New York, N. Y.; Jan. 12, 1956, Legion Hall, Middletown, Ohio, "New Machinery Developments in the Paper Industry," afternoon visit to plants of Black-Clawson Co., Hamilton, Ohio, and Shartle Bros. Machine Co. Division, Middletown, Ohio; Feb. 14, 1956, Legion Hall, Middletown, Ohio, "Stock Preparation," by James d'A. Clark, Consultant, Longview, Wash.; March 8, 1956, Legion Hall, Middletown, Ohio, "Fiber Swelling" lecture and motion pictures by I. H. Isenberg, Institute of Paper Chemistry, Appleton, Wis.; April 10, 1956, Legion Hall, Middletown, Ohio, Awards Program; and May 10, 1956, Hartwell Club House, Cincinnati, Ohio, Annual Meeting.

Empire State Northern District: Nov. 10, 1955, "The Offset Process Paper Requirements," by E. A. Luscomb, Miehle Printing Press & Mfg. Co., Chicago, Ill.; Dec. 8, 1955, "Printing Problems of the Publisher and New Developments in the Printing Field," by Frank Lincoln, Time, Inc., Springdale, Conn.; Jan. 12, 1956, Students Night, "Beater Additives," by S. Earll Church, College of Forestry, State University of New York, Syracuse, N. Y.; Feb. 9, 1956, "Machinery Developments," by representatives of Sandy Hill Iron & Brass Works, Hudson Falls, N.Y.; March 8, 1956, "Titanium Pigments in Paper," by H. C. Brill, E. I. du Pont de Nemours & Co., Newport, Del.; April 12, 1956, Empire State Award Night; and May 10, 1956, Annual Meeting.

Delaware Valley: Engineers Club, Philadelphia, Pa., Oct. 27, 1955; Dec. 9, 1955; Jan. 26, 1956; March 29, 1956; April 26, 1956; and May 31, 1956.

Empire State Eastern District: Queensburg Hotel, Glens Falls, N. Y., Oct. 21, 1955; Nov. 18, 1955; Dec. 16, 1955; Jan. 20, 1956; Feb. 17, 1956; March 16, 1956; April 20, 1956; and May 18, 1956.

Chicago: Chicago Bar Association Rooms, 29 South La Salle St., Chicago, Ill., Nov. 14, 1955; Dec. 12, 1955; Jan. 9, 1956; Feb. 13, 1956; March 12, 1956; April 9, 1956; and May 14, 1956.

Empire State Metropolitan District: Fraunces Tavern, Pearl and Broad Sts., New York, N. Y., Nov. 15, 1955, Speaker—W. Boyd Campbell, Consultant, Montreal, P. Q.; Dec. 13, 1955, "Technical Manpower—Its Opportunities and Responsibilities," by Hugh G. Wyland, H. G. Wyland, Associates, New York, N. Y.; Jan. 10, 1956, Panel Meeting—subject to be announced; March 13, 1956, Panel Meeting—subject to be announced; April 10, 1956, and May 8, 1956, Annual Meeting.

TAPPI National Conferences

Ninth Alkaline Pulping Conference: Hotel Patten, Chattanooga, Tenn., Oct. 19–21, 1955.

Tenth Engineering Conference: Rice Hotel, Houston, Tex., Nov. 7–9, 1955.

Seventh Coating Conference: Benjamin Franklin Hotel, Philadelphia, Pa., May 7–9, 1956.

TAPPI 1956 Medal

By vote of the Executive Committee of the Technical Association of the Pulp and Paper Industry, the TAPPI Medal has been awarded to Harry F. Lewis of The Institute of Paper Chemistry, Appleton, Wis.

The medal is awarded to a person who has made outstanding contributions to the technical advancement of the pulp and paper industry.

The presentation will be made at the TAPPI Annual Meeting luncheon on Thursday, February 23, 1956, at the Commodore Hotel, New York, N. Y. The accomplishments of Mr. Lewis will be outlined during the presentation address.

Mr. Lewis was born in Denver, Colo., on May 27, 1891, and graduated from Wesleyan College in 1912. He received his doctorate in chemistry from the University of Illinois in 1916 and honorary doctorates from Cornell Coll. (Iowa), in 1945 and from Wesleyan College in 1948.

In 1916 and 1917 he did pharmaceutical chemistry research

work at the University of Illinois. In 1917–18 he worked for the Department of Agriculture. He was associate professor of chemistry at the University of Maine in 1918–19. From 1919 to 1921 he was a research chemist for the National Aniline & Chemical Co. From 1921 to 1928 he was professor of chemistry at Cornell College and from 1928 to 1930 he was head of the chemistry department of Ohio Wesleyan College. Since 1930 he has been dean of students at The Institute of Paper Chemistry.

His service as an educator has been outstanding. Some of his exceptionally fine work has been done in the field of redwood chemistry, lignin and its conversion to useful products, permanence of paper, chemistry of bark, and the structure and properties of vegetable tannins.

CPPA Technical Section

The Technical Section Annual Meeting will take place at the Sheraton-Mt. Royal Hotel, Montreal, P. Q., on Jan. 25–27, 1956. The Annual Meeting invariably overloads available accommodation facilities, therefore requests for reservations should be made early to T. L. Deveau, general manager of the Hotel.

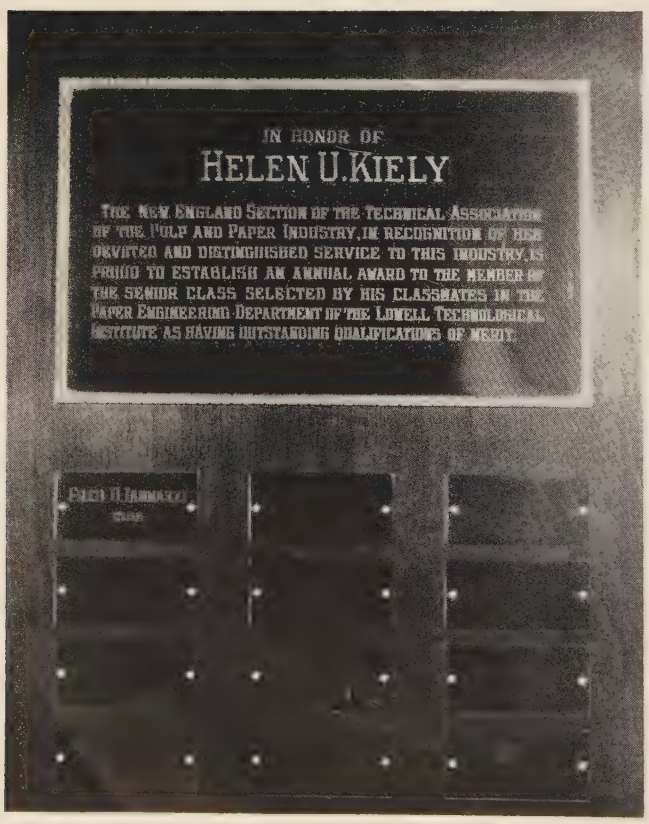
Anyone wishing to present a paper at this meeting should contact Douglas Jones, executive secretary, Technical Section, Canadian Pulp & Paper Assn., 2280 Sun Life Building, Montreal 2, P. Q.

New England

At the annual meeting of the New England Section held at the Oceanside Hotel, Magnolia, Mass., in June, a plaque was awarded to a student of the Paper Engineering Course of the Lowell Technological Institute, Lowell, Mass.

This plaque was presented to Fred D. Iannazzi, Class of 1956, by Miss Helen V. Kiely, former technical director of the American Writing Paper Co., Holyoke, Mass.

The placque was established by the TAPPI New England Section to honor Miss Kiely for her many years of devoted and distinguished service to the pulp and paper industry.



The plaque will be on permanent display in an exhibit area in the Paper Engineering Building of Lowell Technological Institute.

Tenth Plastics-Paper Conference

The Tenth Plastics-Paper Conference of the Technical Association of the Pulp and Paper Industry will be held on November 14 and 15, 1955, at the Brooklyn Law School, 375 Pearl St., Brooklyn, N. Y. The theme of the conference will be "Plastic Modified Functional Papers."

The program follows:

Nov. 14, 1955

9:30 a.m. "Fibrous Materials for Laminates"

Paul M. Goodloe, Brown Co., Berlin, N. H.

1. "Some Factors Influencing the Crazing Tendency of Laminates," Hans Arledter, Hurlbut Paper Co.
2. "The Forming Machine—Its Use in Sheet and Preforming Operations," F. Carlton Loeber, The Forming Machine Co. of America, Inc., and Frank Hayes, Noble & Wood, Inc.
3. "Kraft and Synthetic Fiber Pulp Mats for Laminates," L. P. Wenzell, Celanese Corp.
4. "A Preliminary Investigation of Paper-Laminate Property Relationships," George Shaw, Taylor Fiber Co.
5. "Factors Affecting the Electrical Properties and Fire Resistance of Phenolic Paper Laminates," Myer Ezrin, Monsanto Chemical Co.
6. Panel Discussion—"Testing Paper for Resins Saturating Qualities" (time permitting).

Nov. 14, 1955

2:00 p.m. "Resins Employed in Laminates"

H. F. Mark, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

7. "Board Surfacing Resin," R. Lindenfelser and H. P. Ledden, American Cyanamid Co.
8. "Titanium Organic Polymers and Their Use with Fibers," H. C. Brill, E. I. du Pont de Nemours & Co.
9. "Polyesters," H. L. Gerhart, Pittsburgh Plate Glass Co.
10. "Epoxy Resins and Their Use with Fibers," P. A. Thomas, J. L. Welch, Jr., and B. E. Godard, Bakelite Div., Union Carbide and Carbon Corp.

Nov. 15, 1955

9:30 a.m. "The Pulp and Paper Industry Speaks on its Plastics Requirements"

W. Stickel, Texon, Inc., South Hadley Falls, Mass.

11. "Specialty Papers," J. F. Helms, Marathon Corp.
12. "Glassine," Ralph Nazzaro, Westfield River Paper Co.
13. "Boxboard," A. T. Luey, The Boxboard Research Assn.
14. "Cup and Container," Henry Maeder, Dixie Cup Co.

Luncheon

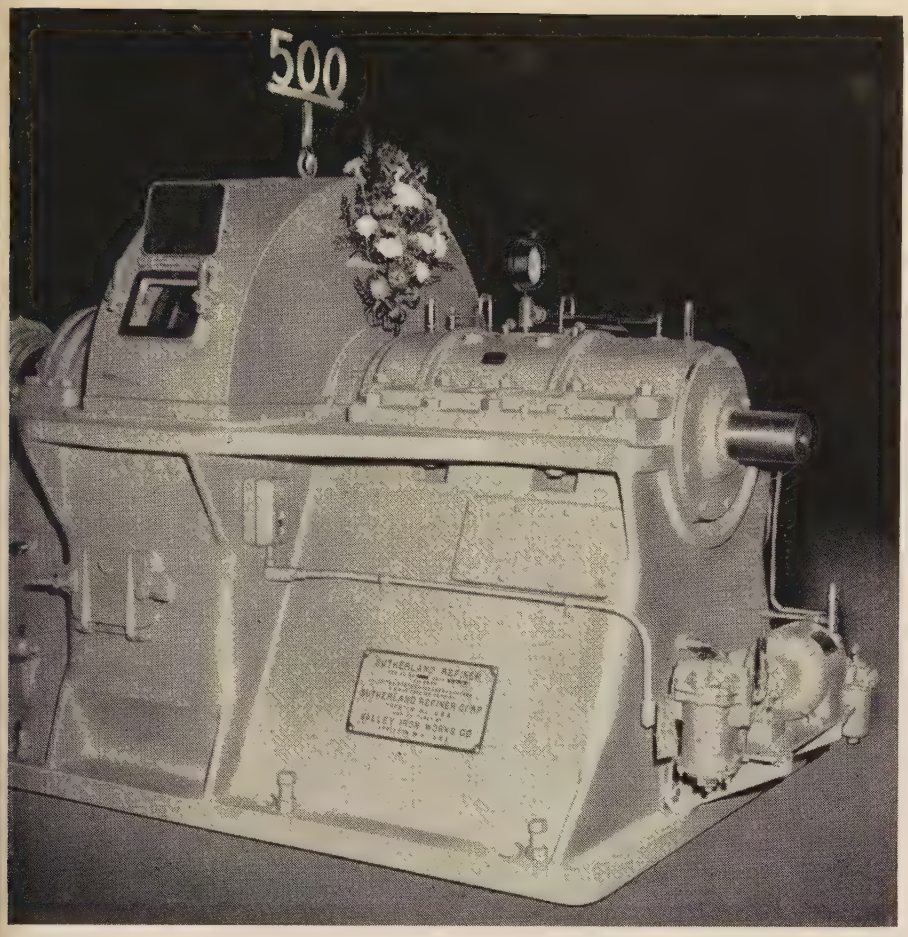
A luncheon will be held at the Bossert Hotel, 98 Montague St., Brooklyn, N. Y. Charles Lewis, Director, Container and Packaging Division, U. S. Department of Commerce, will be the luncheon speaker. His talk will be an off-the-record discussion of "Government Plans for the Industrial Mobilization of the Paper and Plastics Industries."

Nov. 15, 1955

2:00 p.m. "Polyethylene Extrusion Coating"

R. C. Sturken, Frank W. Egan & Co., Somerville, N. J.

15. "Physical Properties of Papers Coated with Polyethylene by Extrusion," Kenneth A. Arnold, St. Regis Paper Co.



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16. "Performance and Design Data of Cooling a Roll on Polyethylene Extrusion Laminating Machine," William R. Penrod, Dilts Machine Works.
17. "A Comparison of Polyethylene and Polyethylene-Wax Paper Coatings," John C. Rice, Lowe Paper Co.
18. "Polyethylene Extrusion Lamination—Equipment Design and Operation," Ernest C. Bernhardt, E. I. du Pont de Nemours & Co.

Note: Reservations for sleeping accommodations should be made directly with the hotel of your choice. The St. George Hotel, Clark St., Brooklyn, is convenient to the Brooklyn Law School and is situated on a subway station a short ride from Manhattan. The registration fee for the conference will be $10 for TAPPI members, $13 for non-members

Seventh Coating Conference

At the second meeting of the 1956 Coating Conference Committee on August 30, Chester Landes, program chairman, announced that a large selection of papers had been submitted for the next coating conference to be held in Philadelphia May 7 to 9, 1956. The committee has requested that paper titles and authors be submitted no later than Nov. 1, 1955.

The Program Committee indicated the need for more papers from operating mills and members of the graphic arts industry.

Mr. Landes has appointed the following men to the Program Committee:

H. C. Brill, Pigments Dept., E. I. du Pont de Nemours & Co., Newport, Del.
K. A. Craig, Kimberly-Clark Corp., Neenah, Wis.
L. E. Georgevits, The Borden Co., Chemical Division, Bainbridge, N. Y.
Gerald Haywood, West Virginia Pulp & Paper Co., Luke, Md.
A. H. Nadelman, Paper Technology Dept., Western Michigan College, Kalamazoo, Mich.
A. W. Neubauer, Crown Zellerbach Corp., Camas, Wash.
F. L. Schucker, Rohm & Haas Co., 5000 Richmond St., Philadelphia 37, Pa.
G. S. McKnight, Jr., Oxford Paper Co., Rumford, Me.

Anyone interested in presenting a paper should contact any one of the above men, or C. G. Landes, American Cyanamid Co., 1937 W. Main St., Stamford, Conn.

The subject of the 1956 Coating Conference is "Synthetic Adhesives for Paper Coating."

J. T. Loomer, general chairman of the 1956 Coating Conference, has requested that anyone interested in displaying an exhibit at the conference should contact either Emil Padavic, Local Arrangements Chairman, Container Corp. of America, Nixon & Fountain Sts., Philadelphia, Pa., or John C. Rice, Publicity Chairman, Lowe Paper Co., Ridgefield, N. J. This should be done as soon as possible so that the necessary space can be assigned for the exhibits.

Tenth Engineering Conference

The TAPPI Tenth Engineering Conference will be held at the Rice Hotel, Houston, Tex. on Nov. 7–10, 1955. The details of the technical program were published in the September issue of *Tappi*.

A feature of the conference will be the opportunity to visit the mills of the Champion Paper & Fibre Co. at Pasadena, Tex., the East Texas Pulp & Paper Co. at Evadale, Tex., and the Southland Paper Mills, Inc., at Lufkin, Tex.

The following details will indicate what can be seen in these exceptionally fine mills:

The Champion Paper and Fibre Co., Texas Div., Pasadena, Tex.

Pulp mill established 1937, paper mill established 1940.

Aerial view of the Champion Paper & Fibre Co., Texas Div., Pasadena, Texas

Power Plant: Steam and electricity.
Sulphate Pulp Mill: 1,050,000 lb. 24 hr.
Kind: Bleached sulphate.
Bleach Plant: 1,050,000 lb. 24 hr.
Groundwood Pulp Mill: 100,000 lb. 24 hr.
Paper Mill: 930,000 lb. 24 hr.
Kind: Fine machine coated paper, uncoated specialties, bonds, mimeograph, tablet, offset, sanitary food container board.

Major Equipment

Sulphate Mill:
Conveyor: Jeffrey Mfg. Co.
Drum Barkers: 2—D. J. Murray; 1—Fibermaking Processes; 1—Manitowoc Engineering Co.
Chippers: 2—Carthage; 2—D. J. Murray.
Recovery Plant: 2—B&W Tomlinson; 1—Combustion Murray-Wearn; 2—sets quadruple effect evaporators by U. S. Cast Iron Pipe Co.; and 1—set Swenson evaporators by Buffalo-Vac.
Refuse and Gas Boilers: 2—Combustion Engineering; 1—Voght.
Boilers: 4—B & W Express-type gas fired; 1—12,000 amp. 650-volt Westinghouse Mercury Arc Rectifier.
Digesters: 6—Combustion Engineering; 1—Chicago Bridge; 1—Wyatt.
Circulating Systems: Fibermaking Process.
Lime Kilns: 1—Traylor; 1—Montreal.
Causticizing System: Dorr Co.
Pulp Washing: 5—Oliver; 4—Impco; 3—Impco Deknotters.
Screening: Impco Dunbar Flat Screens; 2—Cowan centrifugal screens; Bauer Centri-Cleaner.
Bleach Plant: 2 Complete Impco systems, 525 tons storage and bleaching capacity for sulphate pulp, including 1 Impco high density ClO_2 bleaching stage. 1—3-ton Mathieson system for generating ClO_2.
Chlorine & Caustic: Hooker Electro-Chemical cells.
Pulp Drier: 1—168-in. Black-Clawson fourdrinier; General Electric sectional drive; Mathews presses; Mathews Layboy.
Paper Machines: 1—214-in. Beloit; 1—150-in. Beloit fourdrinier; Pusey & Jones driers; B-C calenders; Beloit drive: 1—140-in. B-C fourdrinier; Manchester machine reel; 1—128-in. B-C cylinder; Langston winder.

Finishing:
Rewinders: 3 Cameron; 1 Beloit.
Supercalenders: 2—194-in. B-C and Beloit; 2—145-in. Appleton, Reliance electric drive; 1—80-in. Champion.
Cutters: 5—Humblet Machine Co.
Trimmers: 6—Harris Seybold.

Groundwood Mill:
Conveyers: Jeffery Mfg. Co.
Drum Barker: Manitowoc Engineering Co.
Grinders: 2—Roberts 66″ face 62″ diameter by Appleton Machine Co.
Stones: Norton, Carborundum.
Pumps: Ingersoll-Rand, Goulds, Mission.
Screens: 3—centrifugal Montague Machine Co.; 1—centrifugal Cowan; 2—flat Jonsson.
Thickeners: 3—8 × 12 Impco.
Storage Warehouse: 65,000 sq. ft.

FULLY-HYDRAULIC SEYBOLD 85″ MILL TRIMMER WITH AUTO-SPACER

● Fully-hydraulic Seybolds are introducing a completely new concept in paper cutting and trimming. In two years of in-plant field testing, they proved to be the most accurate power cutters ever built, and enabled paper mills to trim stock to a uniformity of size, squareness and straightness never possible before.

Built in 65″ and 85″ sizes, the new cutter-trimmers incorporate many Seybold advances in cutter design, hydraulics, and automatic spacing. The new machines permit precision cutting and trimming to extremely close tolerances, while handling a substantial increase in daily tonnage.

Back gauge, clamp and knife bar on these new Seybold cutter-trimmers are hydraulically operated. Improved Seybold Auto-Spacer offers many new advantages in automatic, mass production. Air-film tables are standard equipment.

Fully-hydraulic Seybolds are available in both mill trimmer and commercial finishing models. For a complete list of installations, an on-the-job demonstration, or an illustrated, descriptive booklet, check with your Harris-Seybold representative, or write Harris-Seybold Company, 4510 East 71st Street, Cleveland 5, Ohio.

HARRIS SEYBOLD COMPANY

SEYBOLD CUTTERS

Harris Presses • Seybold Cutters • Harris Litho-Chemicals
Special Products • Cottrell Presses • Platemaking Equipment
Macey Collators

Existing Major Power Plant Equipment at Southland Paper Mills, Inc.

The existing power plant at Southland consists of equipment installed in 1939, 1944, and 1948.

1939

The original plant was built to furnish power for one (1) fourdrinier paper machine operation, including groundwood mill, stock preparation, woodyard, water wells, etc.

The following equipment was installed in power plant:

3—75,000 lb./hr. 750° FTT 650 p.s.i.g. natural gas-fired power boilers.
2—6000-kw., automatic single extraction condensing turbogenerators.
Generators and all main switchgear were 2400 volts.

1944

In 1944 Southland installed an old low pressure 10,000-kw. condensing turbogenerator, a new 120,000 lb. per hr. 500° FTT 200 p.s.i.g. gas-fired boiler power, also, a 200-ton recovery boiler 750°F. 650 p.s.i.g. to handle the addition of the chemical pulp mill.

1947

In 1947 the old 10,000-kw. turbogenerator was junked when the first unit of the new addition was installed.

The 120,000 lb. per hr. low pressure boiler was moved to the woodyard and converted to a combination bark and gas-fired boiler. This bark burning boiler is used as part of the feedwater system in that all treated water during normal operation goes to this boiler and all condensate is returned to the 600-lb. boilers.

The following major new equipment was installed:

2—175,000 lb. per hr. 750° FTT 650 p.s.i.g. gas-fired power boilers.
2—10,000-kw., double automatic extraction condensing turbogenerators.
Generators and all main switchgear were 6900 volts.

The majority of Southland Paper Mill's power is consumed by the groundwood mill on four 4000-hp. 2300 and four 6900-volt synchronous motors with full voltage, across the line starting.

The present time we are operating with a normal load of 36,000 kw. and 285,000 lb. per hr. of 125 and 30 p.s.i.g. process steam.

1955

For the present expansion the following equipment is being installed:

2—175,000 lb. per hr. 750° FTT 650 p.s.i.g. pressure fired furnace, natural gas fuel, power boilers.
2—15,625-kw., single automatic extraction, condensing, turbogenerators.

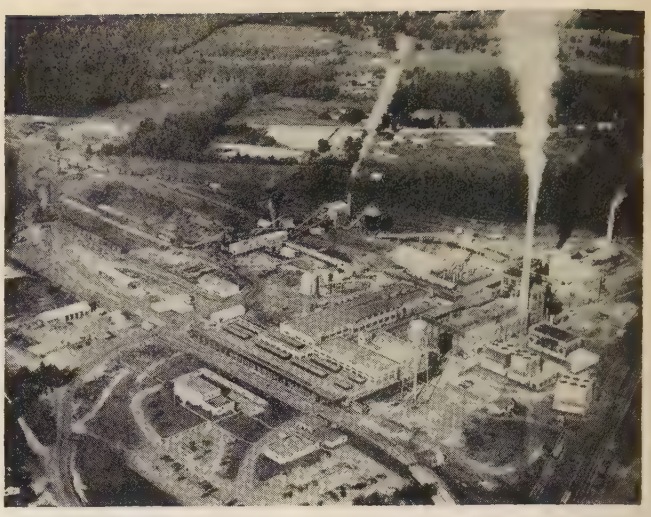
Following the modern trend, a 350 g.p.m. demineralizing plant for boiler feedwater treatment is being installed. All the other necessary equipment needed to build a complete plant as feedwater pumps, condensers, circulating water system, cooling towers, steam distribution system, electrical distribution, etc., has one thing in common, and that is that the old and new systems are tied together during normal operation.

By the time of the TAPPI meeting in Houston, Tex., Nov. 7, 1955, the installation of the boilers will have been completed. The first turbine is due to be delivered the first of November, so one unit should be setting on its foundation by the time of the meeting.

Construction should be in a very interesting stage for TAPPI engineers to take a look on visitors' day, Nov. 10, 1955.

General Electric Co.

2—15,625-kw., single automatic extraction condensing turbines designed for steam conditions of 590 p.s.i.g., 750° FTT, 3 in. Hg abs., direct-connected.
2—15,625-kva., 12,500-kw., 0.80 pf., 0.75 SCR 6900-volt, 3-phase, 60-cycle, air-cooled generators with direct-connected 250-volt exciters.



Aerial view of Southland Paper Mills, Inc., Lufkin, Texas

A. M. Lockett & Co.

2—Babcock & Wilcox integral furnace boilers, class FH26 19 ft. 6 in./NG54—19 ft. 0 in., arranged for pressure firing, each to be designed at 675 p.s.i.g. and each to be selected to produce continuously 175,000 lb. of steam per hour when operating at 610 p.s.i.g., 750° FFT, at the superheater outlet.

Westinghouse Electric Corp.

2—15,000-sq. ft. surface condensers, two-pass, Westinghouse radial flow deaerating type, with nondivided cast iron waterboxes and welded steel shell.

J. F. Pritchard Co

1—Model 6-2454NB15 Induced Draft Pritchard Cooling Tower. To be erected on 12 ft. high concrete basin; 6-cell tower, over-all height 28 1/2 ft. above basin curb; design wind load 30 lb. per sq. ft.; basin dimensions 145 ft. long × 56 ft. wide; tower dimensions—inside length 144 ft., inside width 54 ft., inside height 24 ft., over-all length 145 ft., over-all width 56 1/2 ft., over-all height 28 1/2 ft.

Montague Machine Co.

10—Great Northern Grinders adapted to stone size 67 in. diam. by 54 in. face, installed in tandem, each pair to be driven by 5000 hp. synchronous motor at 240 r.p.m.

Electric Machinery Mfg. Co.

5—5000-hp., 240-r.p.m., 1.0 pf, 6900-volt, 3-phase, 60-cycle, 40°C. rise, synchronous grinder motors.

Reliance Electric & Engineering Co.

1—Sectional Electric Drive for 212-in. Pusey & Jones fourdrinier machine, suitable for speed range of 900 f.p.m. to 2200 f.p.m.

Bailey Meter Co.

Combustion and feedwater control system, for two Babcock & Wilcox pressure-fired boilers.

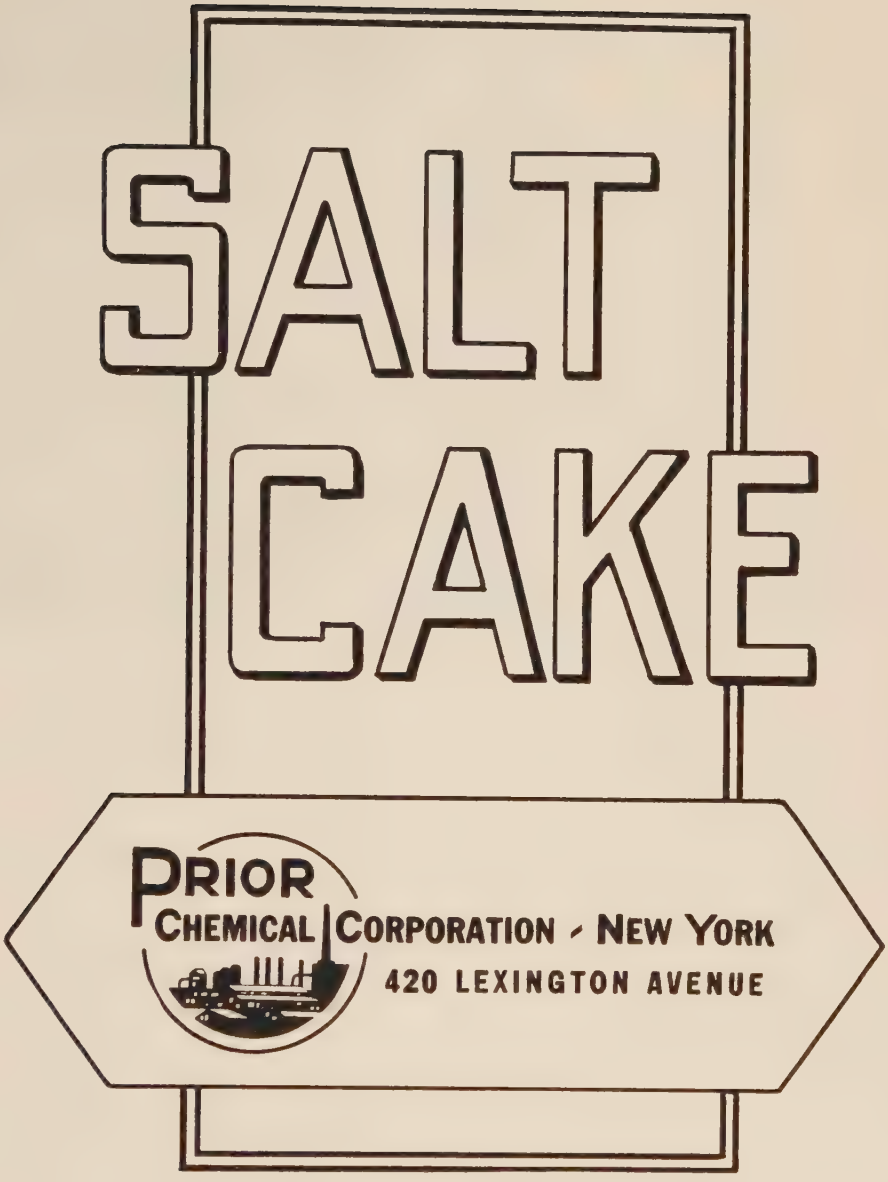
Ingersoll-Rand Co.

Instrument and plant air compressors.

2—5HST 6-stage horizontally split, single suction diffuser type boiler feed pumps with hydraulic balancing device.

Electric Machinery Mfg. Co.

2300-volt motor control centers.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General Electric Co.

Unit substations and transformers.

Warret Electric Co.

440-volt control centers.

Interesting Facts About the East Texas Pulp and Paper Co.

Location: Evadale, Tex.—7 miles East of Silsbee, 24 miles North of Beaumont.
Construction Period: Started construction—Sept. 1, 1953; began operations—Dec. 5, 1954; still a little construction in progress.
Size: Plant area—50 acres, with 50 surrounding acres landscaped.
Payroll: 450 employees—annual payroll of over two million dollars.
Timber Purchase: $2.8 million annually for purchase of pulpwood from large and small tracts.
Wood Source: Use 200,000 cords of pine and hardwood annually. 100,000 cords—Southwestern Settlement and Development—Chips from Kirby Lumber Co. equivalent 40,000 cords. Remainder from individual tree famers and landowners.
Water Used: 23,000,000 gallons per day (75,000 gallons used for one ton of product).
Water Source: Eight wells—1400 ft. deep, yielding 2000 to 2300 gallons per minute. No water from Neches River is used.
Water Storage: For mill process use, a water storage tank of 850,000-gallon capacity is provided. Also for fire protection an elevated storage tank with a 125,000-gallon capacity is provided.
Effluent Disposal: A 14-mile effluent canal constructed from the mill and terminating in a 5500-acre swamp area which is the property of Eastex. This area is situated some miles below the intake for Beaumont's water supply. During the effluent's passage down this 14-mile canal and swamp area, it becomes stabilized so that no nuisance is passed into the Neches River.
Production: Three hundred (300) tons daily of bleached kraft market pulp and paper, provided for domestic and export markets. The market pulp is shipped to paper mills who do not have their own pulp or must supplement their supply. Also included are bleached fourdrinier board grades (both coated and uncoated) and heavy weight bleached paper. This paper is used primarily in the manufacture of milk containers, cartons, cups, cans, plates, trays, tags, folders, and similar paper products.

Your tour will be generally in the order that the log follows from "pine to paper," and you will see each step that it goes through. At some of our stops it may be difficult to ask and answer questions, and we hope that this tour information sheet will be of some help to you.

Listed below are the places you will stop and actually see the phases of operation in converting pine to paper.

Laboratory

The laboratory personnel are responsible for all technical control work for the processes throughout the plant. They gather data on operations, raw materials, and the physical properties of pulp and paper during manufacture.

It is here that the color formulas necessary to manufacture the shades of paper board requested by the customer are made up.

From each reel of paper turned out by the paper machine, one set (12 × 12 × 12) is taken and tested for these various qualities—folding endurance, tearing resistance, stiffness, burst, tensile, smoothness, porosity, weight, and thickness.

The sampling department of the laboratory sends samples of container board and other grades to prospective customers.

Power House

The power plant generates about 65% of the total electrical energy used in the mill, and the remainder is purchased from Gulf States Utilities Co. Steam for power generation and process requirements is obtained from two boilers. One boiler burns pine bark and natural gas as fuel, and the other boiler burns black liquor as fuel. Black liquor is a lignin residue left in the chemical after cooking the useful cellulose fiber from pine wood chips. Natural gas fuel produces about 30% of the mill steam requirements. Black liquor and pine bark produce the other 70% of steam required.

Aerial view of East Texas Pulp & Paper Co., Evadale, Texas

Woodyard and Wood Mill

There are two huge woodyards each with an area of 64,000 sq. ft., and a storage capacity of 20,000 cords of wood. This wood is stacked in piles 30 ft. high by cranes. A specially constructed flume 750 ft. in length is filled with water which recirculates at a rate of 20,000 g.p.m. and is used to float the logs to the barking drums.

The wood mill has the job of converting logs into chips that are suitable for conversion into pulp. The logs are barked by two huge drums, 12 ft. in diameter and 45 ft. long, which revolved on their longitudinal axis. The logs are washed and sized, and sent to the chipper. In the chipper the log is brought in contact with a series of knives fastened on metal disks. This reduces the wood to chips. The chips are then screened and conveyed by belt to the storage silos.

Each of these silos is 40 ft. in diameter and 65 ft. high. They each have a chip capacity equivalent to 200 cords of wood.

Pulp Mill

In this operation the chips are fed to four digesters where they are cooked under elevated temperature of 350° and pressure conditions of 110 lb. A white liquor consisting of alkali and sulphur compound is poured in to dissolve the lignins and other binding materials from the cellulose fibers of the chips. This cooking continues for about $3^1/_2$ hr.

After cooking, the pulp is washed and screened. After screening, pulp that is to be bleached is sent to the bleach plant and then to the beater room.

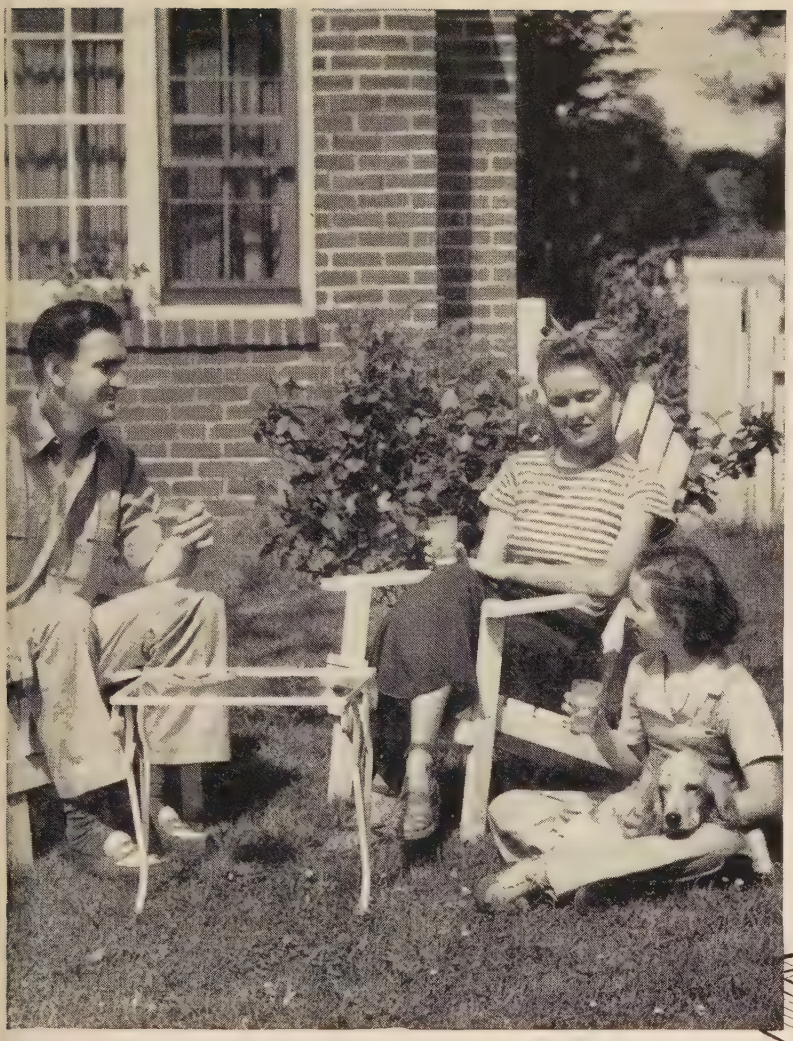
An important part of the pulp mill operation is the recovery department, where certain chemicals used in the manufacture of pulp are recovered to be used again.

The organic materials from the spent liquor are burned in furnaces where the temperature ranges between 1800°F. and 2400°F. The recovery furnace utilizes the heat from the burning chemicals to generate steam at 625 lb. pressure which is used in the steam turbines as was mentioned under the heading power house.

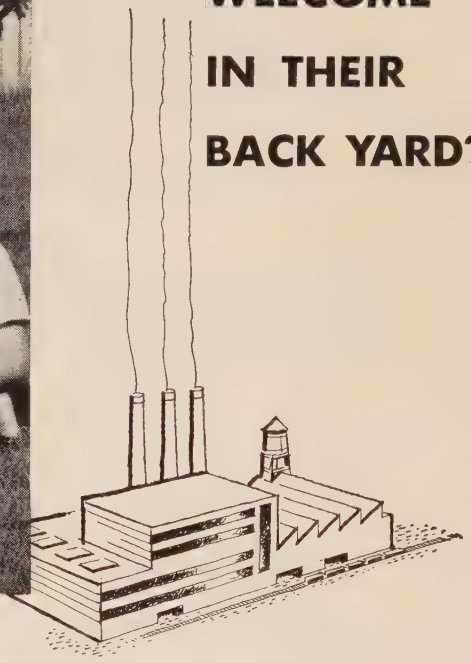
Two important steps in recovery are the treatment that the smelt receives in the caustic room, and that where the lime mud from the caustic room is filtered in the lime kilns.

Paper Mill

From the bleach plant the pulp travels to the beater room, where it receives its final treatment prior to entering the paper machine. Color, size, alum, wet-strength resin, and



ARE YOU WELCOME IN THEIR BACK YARD?



No neighbor has a good word for industrial odors. The morale of plant employees drops, residents see the value of their homes and property taking a nose-dive, local business begins to worry about lost profits.

That's why, when a plant loses its welcome, Airkem's Industrial Odor Service can be an invaluable public relations aid. Everyone, from plant employees to city council, will appreciate the fast, thorough removal of odors—and plant management gets the credit for their public-minded spirit.

If you find yourself faced with an industrial odor problem, Airkem's nation-wide organization can help you turn an odor liability into a public relations asset. Simply call in your local Airkem field representative for a free analysis. Then, with the facilities of the nation's largest osmics laboratory at his disposal, he can recommend the specific Airkem formulations and equipment that will solve your problem rapidly and effectively . . . without interrupting plant production, and at exceptionally moderate cost.

You'll find your Airkem field representative listed in your phone book. Call him today for full information on how Airkem's Industrial Odor Service can help you. Or write to Airkem, Inc., 241 East 44th Street, New York 17, N. Y.

ODOR COUNTERACTANTS FOR INDUSTRIAL USE

airkem

other additives are blended into the pulp. The pulp is also refined by the jordans to give it the proper "freeness." Freeness is a measure of the rate at which water will drain from the pulp suspension (stock).

Perhaps the most impressive single piece of equipment in the East Texas Pulp and Paper plant is the huge paper machine. Cost of the machine is $2.8 million.

The paper machine is 20 ft. wide and 440 ft. long. This machine is essentially a device where the suspension of pulp in water is transferred in an even layer onto a continuously moving screen used to drain water from the pulp. A wet sheet is continuously formed and is subjected to further water removal by suction roll presses and subsequent transfer to a series of dryers which remove more water.

After leaving the drier section the sheet may or may not be subjected to calendering (compressing the sheet) depending upon the type of finish desired. After the paper passes through the calenders it is wound on a steel spool called a reel. From the reel the large roll of 196-in. trimmed paper is transferred to the slitter and winder, where it is slit into narrower rolls. As each roll of paper is made samples are taken for complete analysis of quality.

This giant paper machine is designed to run at speeds up to 1500 f.p.m. which means that it can make a paper sheet 216 in. wide at a rate of 17 m.p.h.

Finishing and Shipping

After the rolls of paper are disengaged from the winders they are transferred either to the rotary cutter to be cut into flat sheets, or to a rewinder to be cut into smaller rolls. The pulp is wrapped in pulp wrapper and baled in bales weighing 500 lb. The shipping rolls are either wrapped or steel strapped, and both pulp and paper are stenciled as to destination and customer specification.

The pulp or paper is now ready for the box cars which line the tracks near the loading platforms. These cars have been thoroughly cleaned, and after inspection are lined with paper on floor and sides to ensure clean shipment. The cars are loaded by fork lift trucks, which have a lift capacity ranging from 3000 to 10,000 lb.

Maintenance

A mill of this size naturally requires a well trained and well equipped maintenance section. The company has a group of experienced craftsmen, versatile enough to take care of practically all of our maintenance problems. You will see a section of our maintenance shops on your tour, and will probably see maintenance personnel at work in some other areas of the plant as you go through.

We hope you will enjoy your tour—feel free to ask your guide any questions you wish as you go through—and come back to visit us again!

Mill Equipment Data Sheet

Woodyard and Chip Storage:

- 2—Wood storage areas 80 × 800—capacity 12,000 cords.
- 1—Lorraine 2¼-yd. crane.
- 1—Lorraine 1-yd. crane.
- 1—Flume—36 in. wide × 36 in. min. deep × 750 ft. long.
- 2—Flume pumps, Bingham, 10,000 g.p.m., 125 hp., 900 r.p.m. Woodyard conveyers by Link Belt.
- 2—Fibermaking barking drums 12 × 45 ft.—capacity each 20 cords per hour.
- 1—102-in. 10-knife Murray chipper; 700 hp., 327 r.p.m., 2300 v., sync. motor.
- 3—Rotex chip screens—20 cords per hour each.
- 1—34-in. Carthage rechipper.
- 1 –Hammermill hog.
- 3—Chip silos 40 ft. diam. × 65 ft.—capacity 200 cords each.
- 3—17 ft. diam. Link Belt table chip feeders—silos to belt.

Digester Building:

- 4—Indirect cooking digesters by Chicago Bridge & Iron 11 ft. 6 in. diam. × 54 ft. h., capacity 4800 cu. ft. or 12 tons each with Esco circulating systems, operating on 150 lb. steam.
- 1—Blow tank—Chicago Bridge & Iron—26 ft. diam. × 54 ft. h., turpentine recovery system.
- 3—Jonsson knotters.
- 3—Impco Brown stock washers—9½ ft. diam. × 16 ft.
- 3—Seal tanks.
- 1—Foam tank.
- 2—Unbleached high density storages—17 × 46 ft.—capacity 35 A.D. tons each at 11% stock.

Screen Room:

- 1—Blending tank—30 × 38 ft. h. capacity 40 tons at 3½%. Unbleached screening—Impco 14-plate flat screens. 8 lines—3 screens each.
- 1—Impco valveless Brown stock deckers 9½ × 16 ft.
- 2—Unbleached decker stock chests at 4% consistency.

Bleach Plant:

- 5—Stage Impco bleaching system.
- 5—Impco washers 8 × 14 ft.
- 1—Low density chlorination tower—15 diam. × 70 ft. h.
- 4—High density towers—17 ft. 6 in. × 46 ft.
  Sequence:
  (1) Chlorination—8 × 14 ft. washer—rubber covered.
  (2) Caustic—8 × 14 ft washer—rubber covered.
  (3) Hypochloride—8 × 14 ft. washer—cast iron.
  (4) Hypochloride—8 × 14 ft. washer—cast iron.
  (5) Chlorine-dioxide—8 × 14 ft. washer—317 S.S.
- 2—High density storage tanks—concrete—tile lined. Bleached screening—Impco 14-plate flat screens. 4 lines—3 screens each.
- 1—Impco valveless bleach stock decker 9½ × 16 ft.
- 2—Bleached decker stock chests at 4½% consistency.
- 1—Chlorine unloading and evaporating system.
- 1—Calcium hypochloride (bleach liquor) system.
- 1—Chlorine-dioxide system including:
  Liquid sulphur storage.
  Sulphur burner.
  Sulphuric acid unloading and storage.
  Sodium chlorate unloading and storage.
- 1—Mathieson chlorine-dioxide generator ClO_2 storage.

Recovery:

- 2—Weak black liquor storage tanks.
  Sextuple effect evaporators—Goslin-Birmingham, capacity 170,000 lb.
  Water per hour with 33,700 lb. steam per hour at 40 lb. pressure.
  Soap recovery system.
- 1—Fuller airveyor salt cake handling system.
- 2—Strong black liquor storage tanks.
- 2—Cascade evaporators.
- 1—CE recovery unit burning 900,000 lb. of solids per day and generating 132,000 lb. of steam per hour at 625 lb. pressure.
- 1—Koppers precipitator—capacity 1,000,000 lb. solids per day.
- 1—Chimney by Costodius Engineers—12 ft. diam. by 200 ft. high.

Recausticizing:

- 1—Limestone storage.
- 1—Oliver mud washer 6 × 6 ft.
- 1—Traylor lime kiln 8 × 250 ft. long.
- 1—Peabody scrubber.
- 2—Dorr slaker No. 4 and No. 8.
  Dorr recausticizing system.

Power Plant:

- 1—Cochran demineralizing feed water system—60 gal. per minute.
- 1—Babcock & Wilcox power boiler, gas-fired, 230,000 lb. per hour at 625 lb. pressure with a spreader stoker for bark burning.
- 1—C-E Turbine generator—7500-kw., single extraction, non-condensing.

Mill Water Supply:

- 8—Wells—1200–1600 ft. depth—capacity 1500–2300 g.p.m. each equipped Layne & Bowler Deep Well Turbine Pumps—total capacity 16,000 g.p.m. or 23,000,000 g.p.d.
- 1—Fresh water storage tank—capacity 850 gal.
- 3—Bingham mill supply water pumps—capacity 6,000 g.p.m. each.
- 1—Elevated tank—Chicago Bridge—125,000 gal. 125 ft. high —fire protection.

Beater Room:

- Raw stock storage—50 tons at 4%.
- 4—Stock mixers—2 air-dried tons each at 4%—equipped with Shartle propeller type agitator.
- 1—Beater dump chest—13 tons at 4%.

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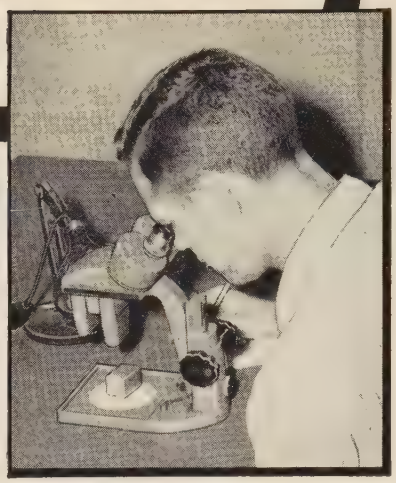
FERROUS and NON-FERROUS CENTRIFUGAL CASTINGS FOR ROLL SHELLS, COVERS, and LINERS



Many concerns are discovering strong, uniform, closely grained Sandusky centrifugal castings are essential to applications requiring maximum strength and extreme resistance to heat, corrosion, and abrasion. Chief Sandusky continuous research is ever expanding the range of these uses.

This versatility and quality results from constant research and testing in our modern firm and independent laboratories. Vast foundry and field experience also assists in supplying the proper castings for you.

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3—Pretreatment lava filled Jones majestic jordans.
1—Jordan dump chest—13 tons at $3^1/_4$ %.
3—Jones majestic wide tackle jordans.
2—Jones majestic narrow tackle jordans.
8—Jordan motors—400 hp., 360 r.p.m. synchronous.
1—Machine chest—$5^1/_2$ tons at 3%.
1—Impco valveless decker saveall, 9 ft. 6 in. × 16 ft.
1—Jones high-speed broker refiner.
Additive systems for:
Liquid alum.
Size.
Starch.
Dye.

Paper Machine 216-in. Beloit at 1500 r.p.m.:
1—Worthington fan pump—20,000 g.p.m.—300 hp., 514 r.p.m. syn. motor driven.
Pressure head box.
216 in. × 130 ft. wire.
42-in. suction couch.
Suction first press.
Inverted suction second press.
6 paper driers and 1 felt drier.
Third press.
Smoothing press.
20 paper driers and 8 felt driers.
Breaker stack.
22 paper driers and 4 felt driers.
Size press.
11 paper driers and 2 felt driers.
First calender stack.
3 driers.
Second calender stack.
Beloit reel.
Beloit double drum winder.
1 Cameron 90 in. rewinder.
Roll refinish line including wrapper, header, scales, and lowerator.

Auxiliary Equipment:
Drive—1500 hp., G.E. turbine with line shaft and Beloit differential gear units.
5 Roots-Connorsville vacuum pumps.
Jones double roll stock master broke beater.
Lobdell roll grinder.

Pulp Line in Basement:
Lambs-Gray Harbor 210 in. simplex cutter and layboy.
Washington Iron Works hydraulic baling press.
Lambs-Gray Harbor baling equipment.

Finishing Room:
1—Moore & White 120-in. duplex precision cutter with layboy.
1—84 in. Seybold trimmer.

TENTH

Engineering Conference

TAPPI

Rice Hotel, Houston, Texas

November 7–9, 1955

THE "VANCEOMETER" is the outstanding photoelectric absorption tester in the Paper Industry and Allied Fields.

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- To measure the receptivity of paper and paper board for sizing, coating, adhesive, ink, etc.,
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- To get results in less than one minute.

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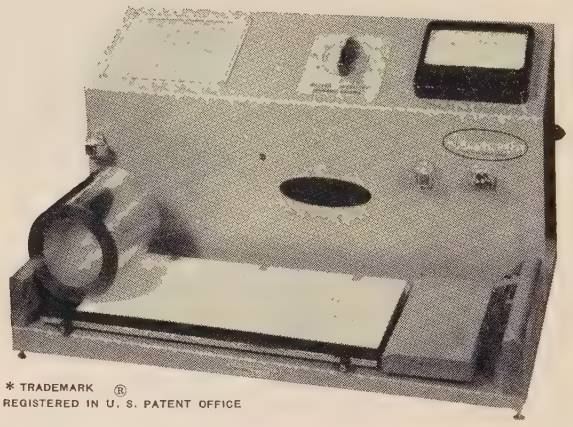

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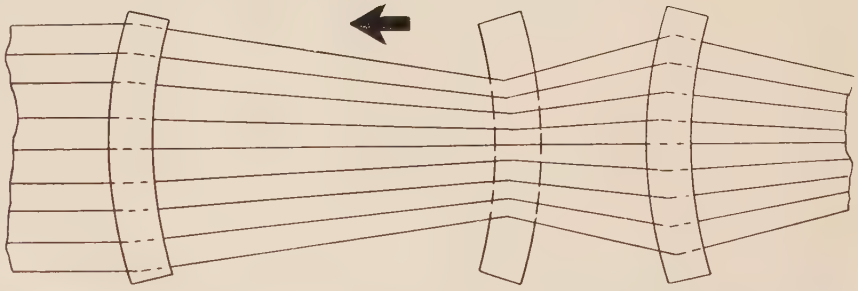
How Thorough Cleaning Adds Valuable Felt Life



Mount Hope Felt Preserver Method Proves Exceptional

In six swift, sure steps the Mount Hope method adds important life to felt.

Step 1. . . . . Wets Felt: A shower soaks and softens felt.

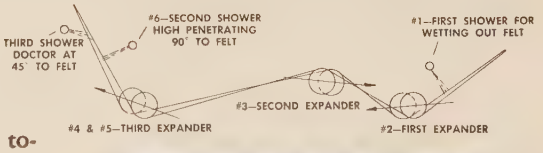
Step 2. . . . . Opens Felt: Expander spreads felt and opens weave.

Step 3. . . . . Squeezes Felt: Expander gently squeezes weave together, without wrinkling.

Step 4. . . . . Spreads Felt: Expander spreads weave open to maximum width.

Step 5. Keeps Seams Straight: Eliminates bowed felt weft.

Step 6. . . . . Washes Felt: Stock, freed and dislodged by "working" action, is now forced to face of felt by a penetrating shower, and washed away by a doctoring shower.


THIRD SHOWER DOCTOR AT 45° TO FELT
#6—SECOND SHOWER HIGH PENETRATING 90° TO FELT
#1—FIRST SHOWER FOR WETTING OUT FELT
#3—SECOND EXPANDER
#4 & #5—THIRD EXPANDER
#2—FIRST EXPANDER

Result: A thoroughly clean, open, soft felt with spring text nap.

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PERSONAL MENTION

Items About New and Old Tappimen

New Tappi Members

Richard G. Anderson, Technical Representative, United States Movidyn Corp., Chicago, Ill., a 1948 graduate of the University of Wisconsin.

Paul August, Sales Engineer, Industrial Nucleonics Corp., Columbus, Ohio, a 1951 graduate of Ohio State University.

Thomas W. Bauer, Research Chemist, Abitibi Power & Paper Co. Ltd., Sault Ste. Marie, Ont., Canada, a 1944 graduate of McGill University with a Ph.D. degree from Ohio State University in 1950.

Earl E. Berkley, Director, Fiber & Spinning Laboratory, Anderson, Clayton & Co., Houston, Tex., a 1933 graduate of Washington University with a Ph.D. degree.

Mario Biondetti, Chief Engineer, Paper Machine Branch, De Pretto-Escher Wyss S.p.A., Schio (Vicenza) Italy, a 1941 graduate of the University of Padova.

Karl Bollerslev, Technical Adviser, Giustina Bros. Lumber Co., Eugene, Ore., a 1931 graduate of the University of Washington.

David Bookshester, Midwest Sales Manager, Paisley Products, Inc., Chicago, Ill., a 1935 graduate of the University of Illinois.

Walter Braun, Director, Cellulose Laboratory, Papierfabrik J. H. Eppen, Winsen/Luhe, Germany, a 1955 graduate of the Technical University, Darmstadt.

Loren J. Brewer, Chemist, Marathon Corp., Rothschild, Wis., a 1940 graduate of the University of Wisconsin.

William E. Caldwell, Jr., Resident Manager, St. Regis Paper Co., Kalamazoo, Mich., a 1937 graduate of the University of Virginia.

E. J. Chagnon, Executive Vice-President, Albany Felt Co. of Canada Ltd., Cowansville, P.Q., Canada, a 1931 graduate of Philadelphia Textile Institute.

John K. Coppens, Sales Engineer, H. Waterbury & Sons Co., Oriskany, N. Y., a 1955 graduate of the University of Maine.

Donald B. Dailey, Assistant General Manager, Standard Chemical Ltd., Beauharnois, P.Q., Canada, a 1937 graduate of St. Lawrence University.

Robert W. Davison, Research Chemist, Hercules Powder Co., Wilmington, Del., a 1950 graduate of Massachusetts Institute of Technology with a Ph.D. degree.

Ivah T. Deane, Librarian, Stromberg-Carlson Co., Rochester, N. Y.

P. R. B. Dixon, Vice-President, Harry Dixon & Sons, Inc., New York, N. Y., a 1934 graduate of McGill University.

Harold M. Ely, Senior Chemist, Potlatch Forests, Inc., Lewiston, Idaho, a 1943 graduate of the University of Michigan.

Richard R. Gardner, Staff Engineer, Buckeye Cotton Oil Co., Memphis, Tenn., a 1947 graduate of the University of Rochester.

Donald B. DeNoyer, Vice-President in charge of Engineering, Valley Iron Works Co., Appleton, Wis., a 1937 graduate of the University of Wisconsin.

Emmanuel J. Dufault, Research Chemist, Canada Packers Ltd., Toronto, Ont., Canada, a 1942 graduate of the University of Western Ontario.

A. Sagarra Fernandez, Chief Chemist, Refinadora Paulista S. A., Sao Paulo, Brazil, a 1946 graduate of the Industrial University, Barcelona.

Marvin F. Gade, Systems Engineer, Kimberly-Clark Corp., Neenah, Wis., a 1952 graduate of the State University of Iowa.

George Gero, Field Engineer, Container Laboratories, Inc., New York, N. Y., a 1950 graduate of Columbia University.

Ernesto G. Gietz, Technical Director, Instituto Biblio-tecologico, Buenos Aires, Argentina.

George E. Gunton, Vice-President, Charles Tennant Co. (Canada) Ltd., Montreal, P.Q., Canada. Attended McGill University and the University of Illinois.

David O. Hamer, Jr., Technical Sales, Arkansas Company, Inc., Newark, N. J., a 1942 graduate of Lowell Technological Institute.

Thomas J. L. Henson, Packaging Development, Thatcher Glass Mfg. Co., Inc., Elmira, N. Y., a 1942 graduate of Pennsylvania State University.

John S. Holmes, Process Engineer, Delco Radio Div., GMC, Kokomo, Ind., a 1947 graduate of Rensselaer Polytechnic Institute.

Ruth H. Hooker, Librarian, Naval Research Laboratory, Washington, D. C., a 1927 graduate of George Washington University.

William T. Jones, Program Executive, Pulp, Paper & Board Raw Materials, Business Defense Services Administration, U. S. Dept. of Commerce, Washington, D. C. Attended the University of Wisconsin.

William E. Kenline, Research Associate, Pierce & Stevens, Inc., Buffalo, N. Y., a 1948 graduate of Canisius College.

Alfred P. Kivlin, Chief Engineer, Freight Loading & Container Bureau, A.R.A., Chicago, Ill., a 1922 graduate of Harvard University.

Stanley J. Kruger, Staff Engineer, Buckeye Cotton Oil Co., Memphis, Tenn., a 1947 graduate of Pennsylvania State University.

Pierre R. Laguilharre, President Director General, Ets. Laguilharre S.A., Enghienles-Bains, France.

Mark La Rue, Sales Engineer, W. E. Greene Corp., Hudson Falls, N. Y., a 1950 graduate of Clarkson College.

John E. Lean, Vice-President, General Manager and Secretary, Rex Paper Co., Kalamazoo, Mich., a 1940 graduate of the University of Chicago.

Yurii E. Lebedeff, Superintendent, Chemical Research, American Smelting & Refining Co., S. Plainfield, N. J., a 1927 graduate of South Dakota School of Mines.

Roberto B. Leonardos, Student, National College of Engineering, Rio de Janeiro, Brazil.

David W. Lovering, Chemist, Arthur D. Little, Inc., Cambridge, Mass., a 1943 graduate of Northeastern University.

Tapani Marttala, Head of Laboratory, Lohja-Kotka O/Y, Lohja, Finland, a 1951 graduate of the Finland Institute of Technology.

Glenn Mather, Managing Director, Fibre Drum Mfrs. Assn., New York, N. Y., a 1913 graduate of the University of Chicago.

James M. McClung, Assistant Plant Engineer, Champion-International Co., Lawrence, Mass., a 1936 graduate of Tufts College Engineering School.

William C. McGinnis, Plant Manager, Continental Can Co., Inc., Los Angeles, Calif., a 1924 graduate of Carnegie Institute of Technology.

Willie E. McGough, Engineering Dept., The Brown Paper

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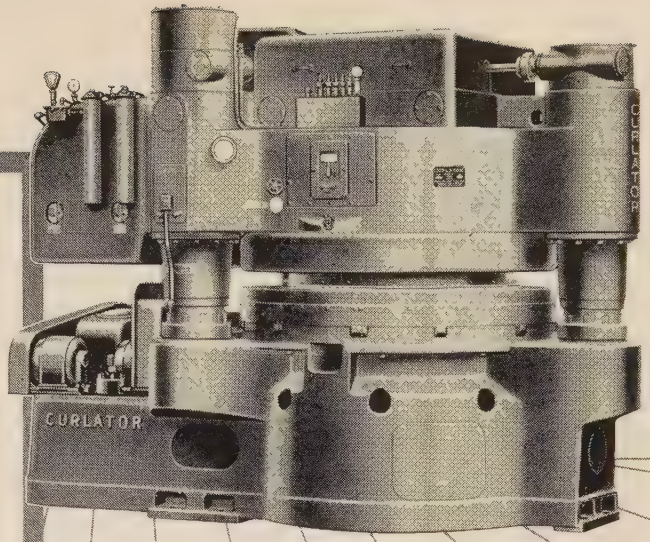

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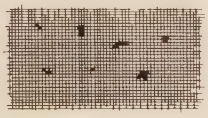

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Mill Co., Inc., Monroe, La., a 1951 graduate of Louisiana State University.

Walter G. Meyer, Chief, Chemical Process Development, Crown Zellerbach Corp., Camas, Wash., a 1929 graduate of State University of Iowa, with a Ph.D. degree from Columbia University in 1935.

Claude R. Mitchell, Chief, Analytical Research, Pulp & Paper Research Institute of Canada, Montreal, P.Q., Canada, a 1924 graduate of McGill University.

Carroll C. Moore, Materials Engineer, Army Ordnance Research Laboratory, Watertown, Mass., a 1927 graduate of New Bedford Institute of Textiles and Technology.

John W. Morrison, Chief Engineer, Gulf States Paper Corp., Tuscaloosa, Ala., a 1939 graduate of the University of Illinois.

John C. Nelson, Chemist, Fox River Paper Corp., Appleton, Wis., a 1949 graduate of Wisconsin State College at Oshkosh.

Teuvo O. Niemioja, Associate for Stream Studies on Pulp Mill Wastes, Sulphite Pulp Mfrs. Research League, Inc., Appleton, Wis., a 1941 graduate of the Technical University of Helsinki.

Charles E. D. Noel, Control Superintendent, Canadian International Paper Co., Montreal, P.Q., Canada, a 1927 graduate of Paris University.

John R. Parkinson, Student, The Institute of Paper Chemistry, Appleton, Wis., a 1951 graduate of Ohio State University.

Sixto J. Peiicchi, Professor, University of Los Andes, Merida, Venezuela, a 1952 graduate of the University of Los Andes.

Earl W. Prince, Supervisor, Instrument Section, Champion Paper & Fibre Co., Hamilton, Ohio, a 1932 graduate of the R.C.A. Institute.

Sven A. Rydholm, Research and Development, Pulp Dept., Billeruds A/B, Saffle, Sweden, a 1948 graduate of the Royal University of Technology.

Kenneth F. Sawyer, Foreman, Great Northern Paper Co., E. Millinocket, Me., a 1952 graduate of Colby College.

Edward P. Schen, Technical Assistant to the Power Plant Superintendent, International Paper Co., Springhill, La., a 1948 graduate of the University of Texas.

William R. Sell, Paper Tester, Wausau Paper Mills Co., Brokaw, Wis.

Raymond V. Shalvoy, Technical Director, Stecher-Traung Lithograph Corp., Rochester, N. Y., a 1947 graduate of the University of Rochester.

Peter G. Sherry, Production Manager, Clondalkin Paper Mills Ltd., Dublin, Ireland, a 1945 graduate of the National University of Ireland with a Ph.D. degree.

William H. Stone, Sales Engineer, National Starch Products, Inc., New York, N. Y., a 1948 graduate of New York University.

John R. Starin, Jr., Technical Service Engineer, Hercules Powder Co., Kalamazoo, Mich., a 1947 graduate of the University of Virginia.

Lester M. Start, Jr., Sales Engineer, Black-Clawson Co., Hamilton, Ohio. Attended North Eastern University.

Tryggve Z. Wiklund, Manager, Voikka Pulp & Paper Mills, Kymmene A/B, Kuusankoski, Finland, a 1921 graduate of the Technical University of Helsingfors.

James E. Wilkinson, General Superintendent, Champion Paper & Fibre Co., Canton, N. C., a 1935 graduate of Virginia Polytechnic Institute.

Harry D. Wilder, Student, Institute of Paper Chemistry, Appleton, Wis., a 1955 graduate of the University of Wisconsin.

Lloyd G. Williams, Project Engineer, Marathon Corp. of Canada Ltd., Marathon, Ont., Canada, a 1949 graduate of Queen's College.

Otto E. Wolff, Engineering Manager, Polaroid Corp., Cambridge, Mass., a 1930 graduate of Massachusetts Institute of Technology.

Frank B. Younger, Manager, Gilbert & Nash Co., Appleton, Wis., a 1943 graduate of Ripon College.

TAPPI Notes

Daniel O. Adams, formerly of Bird & Son, Inc., is now Director of Research for West Virginia Pulp & Paper Co., Covington, Va.

O. P. Aggarwala, formerly a Student at the University of Maine, is now with Parsons & Whittemore Co., located at Black-Clawson Ltd., London, England.

Maung Mai Aung, formerly a Student at the New York State College of Forestry, is now an Appraiser at the Custom House, Rangoon, Burma.

Lothrop B. Bartlett, formerly of the Great Northern Paper Co., is now Manager of Madison Mills, Economy Paper Corp., Madison, Me.

Raymond Basso, formerly of Michigan Carton Co., is now a Technical Representative of the Buckman Laboratories, Memphis, Tenn.

Benno J. Beau, formerly of the Jaite Co., is now Chemical Engineer for the Multiwall Bag Div., National Container Corp. of Ohio, Jaite, Ohio.

Robert S. Birch, formerly Student at the University of Maine, is now Sulphite Mill Engineer for the Donnacona Paper Co., Donnacona, P. Q.

Kenneth G. Booth is now Manager of Administration Services, Central Research Dept., Crown Zellerbach Corp., Camas, Wash.

Charles E. Bouis, formerly of the Central Paper Co., is now Engineer for the Southwestern Engineering Co., Los Angeles, Calif.

Sidney G. Briscoe is now Sales Manager of Pusey & Jones Corp., Wilmington, Del.

Duncan S. Brown is now Assistant to the Vice-President in Charge of Manufacturing of the Gardner Board & Carton Co., Lockland, Ohio.

James S. Brown, formerly of the Marinette Paper Co., is now Production Manager of the Scott Paper Co., Detroit, Mich.

Karl E. Buff, formerly of the Ruberoid Co., is now Consultant for Congoleum-Nairn, Inc., Kearney, N. J.

Max Bunzl, formerly of Tissue Papers Ltd., is now with Papermax Ltd. and Paper Consultants Co., London E. C., England.

Thomas F. Cass is now Senior Vice-President of the Southern California Div., Container Corp. of America, Los Angeles, Calif.

C. Wells Clark is now Chief Chemist of the St. Regis Paper Co., Deferiet, N. Y.

Earl R. Clifford, Jr., formerly Physicist for the Dixie Cup Co., is now in the Research Department, Oxford Paper Co., Rumford, Me.

Robert E. Collins, formerly of Sprout, Waldron & Co., is now Paper Mill Superintendent of No. 2 Mill, The Crossett Co., Crossett, Ark.

Sydney Coppick, formerly of American Viscose Corp., is now a Group Leader for the Scott Paper Co., Chester, Pa.

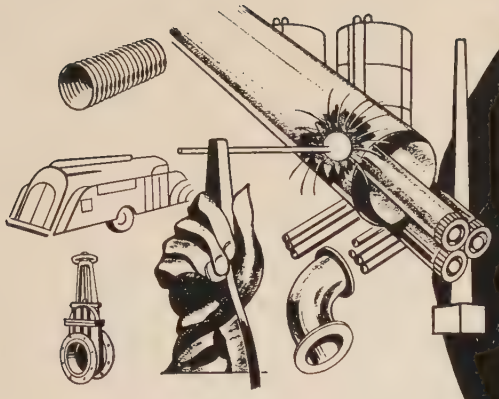
Paul I. Coughlin, formerly Student at the University of Maine, is now in the Technical Service Dept., Eastern Corp., South Brewer, Me.

John W. Crosson is now engaged in Sales Development Work for the Brown Co., Boston, Mass.

Mamerto Cruz, Jr., formerly Chemist with the American Viscose Co., is now with Olin-Mathieson Chemical Corp., Colloid Chemistry Research Dept., New Haven, Conn.

Earl C. Cunningham, Research Engineer of the Pollock Paper Co., has been transferred from Middletown, Ohio, to Dallas, Tex.

Harold A. DeRice, Mechanical Engineer of W. H. Rambo Engineers, is now with Sandwell & Co., Ltd., Vancouver, B. C.



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James G. Dunlap, Jr., formerly of the U. S. Army, is now Chemist for the Rhinelander Paper Co., Rhinelander, Wis.

Russell P. Erickson is now Vice-President in Charge of Engineering and Manufacturing for Rayonier, Inc., New York, N. Y.

A. M. Fairbrother is now Assistant Division Manager of Champion Paper & Fiber Co., Canton, N. C.

Roswell P. Fallon is now Assistant Superintendent of the St. Regis Paper Co., Deferiet, N. Y.

Fred H. Freuler, Project Engineer of the West Virginia Pulp & Paper Co., has been transferred from Luke, Md., to New York, N. Y.

Serge N. Gorbatsevich, formerly a Student at the New York State College of Forestry, is now Research Chemist for the Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis.

Francis P. Haszard, Assistant Manager of Bonar & Bemis Ltd., has been transferred from Vancouver, B. C., to Burlington, Ont.

M. W. Hedden, formerly of the Racquette River Paper Co., may now be reached at Box 515, Mentone, Calif.

Charles J. Higgins, formerly of the Dixie Cup Co., is now an Instructor in the Paper Engineering Dept., Lowell Technological Institute, Lowell, Mass.

Keith B. Johnson, formerly a Student at the New York State College of Forestry, is now Chemist for the Riegel Paper Corp., Milford, N. J.

Morris W. Kane is now Technical Director of the KVP Co., Kalamazoo, Mich.

Neils Klein, formerly of Charles Bruning Co., Inc., is now Director of Technical Papers for the Rising Paper Co., Housatonic, Mass.

Albert J. Krusick, Salesman for Paisley Products, Inc., has been transferred from Cleveland, Ohio, to St. Petersburg, Fla.

Ralph M. Leighton is now Technical Service Manager of Stowe-Woodward, Inc., Newton Upper Falls, Mass.

J. Bicknell Lockhart, Jr. of the Riegel Paper Corp. has been transferred from Riegelsville, N. J., to New York, N. Y., as Merchant and Industrial Sales Manager.

George E. Martin, Chief Chemist of Fibreboard Products, Inc., has been transferred from Antioch, Calif., to the San Joaquin Div.

Mrs. Jean Mater who recently received her Ph.D. degree from the Oregon Forest Products Laboratory is now a Consultant for the Mater Engineering Co., and the Mater Machine Works, Corvallis, Ore.

James H. McClure is now Vice-President of W. C. Ritchie & Co., Chicago, Ill.

Leslie G. McCowan, formerly of the Sorg Paper Co., is now Paper Mill Superintendent of the Racquette River Paper Co., Potsdam, N. Y.

Parker McIntosh is now Paper Mill Superintendent for Sterling Paper Mills, Inc., Kingsey Falls, P. Q.

Carl Magnus, formerly Vice-President of Halltown Paper Co., is now a Management Consultant, Charlestown, W. Va.

George S. Meehan of the St. Regis Paper Co. has been transferred from Herring, N. Y., to Pensacola, Fla., as Assistant Paper Mill Superintendent.

Roy L. Miller of the St. Regis Paper Co. has been transferred from Deferiet, N. Y., to Pensacola, Fla., as Technical Service Engineer.

Walter B. Morehouse is now Assistant Vice-President and General Sales Manager of the Industrial Div., Nopco Chemical Co., Harrison, N. J.

Alfred E. Moyer is now Vice-President of the Snyder Chemical Corp., Bethel, Conn.

John E. Newman, Manager of the Wax Dept., American Mineral Spirits Co., has been transferred from New York, N. Y., to Rahway, N. J.

Remmelt Nijhuis, formerly with Patexol Products, Inc., is now a Salesman for National Starch Products, Inc., High Point, N. C.

Henry J. Ostrowski is now Technical Control Superintendent of the Paperboard and Container Testing Div., Hinde & Dauch Paper Co. of Canada, Ltd., Toronto, Ont.

Raymond S. Owen, Management Engineer, has moved his office from 209 to 231 South La Salle St., Room 852, Chicago 4, Ill.

Arthur M. Patureau is now West Coast Manager of the Pennsylvania Industrial Chemicals Corp., Los Angeles, Calif.

John H. Payne, formerly of Continental Foods, Inc., is now Packaging Engineer for the American Sugar Refining Co., New York, N. Y.

Franz J. Poschmann, formerly of Niederrheinische Papier- und Pappenfabrik A/G, is now with Badische Anilin und Soda-Fabrik A/G., Ludwigshafen/Rhine, West Germany.

Robert H. Quick, formerly Student at The Institute of Paper Chemistry, is now a Project Chemist for the Pulp Div., Weyerhaeuser Timber Co., Longview, Wash.

Sven Quist is now Procurement Manager for Sandwell & Co., Ltd., Vancouver, B. C.

William A. Robinson, formerly of the Hawaiin Sugar Planters Association is now General Manager of the Valentine Pulp & Paper Co., Lockport, La.

Sven A. Salmonson, Consultant, formerly of Portland, Ore., is now located in Prince Rupert, B. C.

George W. Sargent, Jr., formerly of the Ruberoid Co., is now Plant Engineer for Congoleum-Nairn, Inc., Cedarhurst, Md.

Seppo M. Saukkonen, formerly of Metex Cooperative Corp., is now Assistant Technical Manager of Enso-Gutzeit O/Y, Kotka, Finland.

Norman O. Seagrave is now President of the Port Huron Sulphite & Paper Co., Port Huron, Mich.

George E. Scofield of Rayonier, Inc., has been transferred from Jesup, Ga., to Fernandina Beach, Fla., as Resident Manager.

Raymond B. Seymour, formerly President of the Atlas Mineral Products Co., Newhall, Calif.

William L. Schnorbach, formerly of the American Box Board Co., is now Assistant to the Manager of Development, Robert Gair Co., New York, N. Y.

Ronald R. Schutts, Production Trainee of the Armstrong Cork Co., has been transferred from Pennsacola, Fla., to Macon, Ga.

Donald W. Scottung, formerly Student at the University of Massachusetts, is now in the U. S. Army.

Charles R. Stevens is now President of Charles R. Stevens, Inc., Toledo, Ohio.

Harold R. Stoakes, editor of the *American Boxmaker* is now located at 475 N. Santa Cruz Ave., Los Gratos, Calif.

Charles R. Stones, formerly of William Kennedy & Sons, Ltd., is now with the Bowaters Corp. of North America, Montreal, P. Q.

Frank L. Strand, formerly of the Gardner Board & Carton Co., is now Assistant Director of the Paper Products Application Laboratory of American Cyanamid Co., Chicago, Ill.

Edward J. Sullivan is now Manager of the Fine Papers Dept., Bowaters Paper Co., New York, N. Y.

Pekka/Vakomies is now Assistant Chief Development Engineer for Sandwell & Co., Vancouver, B. C.

Jack T. Walker of the West Virginia Pulp & Paper Co. has been transferred from Charleston, S. C., to New York, N. Y. as Manager of Research Development.

Carl T. Welte is now Production Manager for the Champion Paper & Fibre Co., Canton, N. C.

Jack W. Wilson, formerly Assistant Professor at the University of British Columbia, is now Process Development Group Leader for Columbia Cellulose Co. Ltd., Prince Rupert, B. C.

Leonard J. Wood, Jr., of National Starch Products, Inc.,

Progress Marches On

Evidence that progress marches on is supported by some recent research and development triumphs at Orr — triumphs proving exceptionally helpful to some mills—could be equally helpful to many others—to wit:

An-Bac, a specially treated line of felts that successfully combats bacteria—particularly damaging during week end shutdowns—damage that shows up in the form of premature holes and rotted edges.

Orr-Chem, another special line that is chemically treated to offset the ruinous effects of alkaline damage—contact with chlorine, muriatic or sulphuric acid.

Let us repeat. Those two special type felts are already helping a long roster of mills and they could also help you—slash your annual felt bill far more than you realize.

Also standard felts for mills where bacteria or acid contacts are no problem.

Orr

THE ORR FELT AND BLANKET CO.
Piqua, Ohio

has been transferred from Boston, Mass., to New York, N. Y., as Supervisor of Paper Technical Service.

Robert N. Zabe, formerly Associate Professor of Western Michigan College, is now an Engineer in the Pulp and Paper Section, Chas. T. Main, Inc., Boston, Mass.

* * *

Wilhelm Grunewald, Managing Director, has succeeded *Friedrich Klein,* retired, as the official corporate representative of Feldmuhle Papier und Zellstoffeverki A/S. Dusseldorf, Germany, in the Technical Association.

R. S. Jobin, Technical Manager, has succeeded *G. J. Schmitt,* Secretary, as the Official Representative of Tasman Pulp & Paper Co. Ltd., Aukland, New Zealand, in TAPPI.

Industry Notes

Production

At the close of the first half of 1955, the industry had achieved a production of 14,700,000 tons, an advance of 11% over the comparable 1954 period. Thus it was clear that, barring a pronounced slow-down in the current pace of industrial and commercial activity, the total output of paper and board would for the third successive year be at a new high. One can only conjecture what will be the final result, but the recent indication by a major manufacturer of automobiles that during the third quarter assemblies will be maintained at a level substantially higher than was previously anticipated, and the secondary effects of such a change in plans upon the activity of steel manufacturers and other suppliers, should lend additional strength and support to the economy during the present quarter and heighten this industry's prospects for a production approaching 29 million tons.

Perhaps of significance equal to the above is the fact that in the second quarter, mills, although operating at somewhat less than full capacity, produced at an annual rate of more than 30 million tons. The latter fact, coupled with the prospective production for the year, is of such proportion as to possibly warrant a recasting of the industry's current thinking with regard to future supply and demand schedules for its products.

During the first 6 months, all major segments, save building paper, produced at record breaking rates, improvement over the same period of 1954 ranging from 4.5% for tissue paper to 25.8% for newsprint.

Paper and board production during June amounted to 2,548,439 tons, according to the Bureau of the Census, Department of Commerce. This was 12% above the 2,276,510 tons produced in June a year ago. Paper production amounted to 1,075,689 tons, which was 11% above the 967,231 tons produced in June a year ago. The output of paperboard during this month was 1,190,751 tons reflecting an increase of 15% over the production of 1,038,252 tons reported during June 1954.

Pulpwood

Total receipts of pulpwood for 1955 through May amounted to 12,765,000 cords, an increase of 1,658,000 cords above the comparable 1954 period. Receipts of domestic pulpwood increased 1,555,000 cords and imports were up 103,000 cords.

In line with continuing high wood pulp production, consumption of pulpwood in the first 5 months of this year rose to 13,648,000 cords, an increase of 1,769,000 cords above consumption for the comparative months last year.

Wood Pulp

May production of wood pulp reached a record high of 1,788,000 tons. For the January–May period, production totaled 8,501,000 tons, an increase of 1,058,000 tons above production for the comparable period in 1954.

Wood pulp consumption continued at a high rate in May and for the first 5 months of this year was 8,737,000 tons, an increase of 953,000 tons above the comparative months last year.

Imports of wood pulp for 1955 through May were 858,187 tons, an increase of 58,930 tons. Imports from Canada increased 67,153 tons, while shipments from overseas were down 8223 tons.

Exports of wood pulp for the January–May period this year were 270,532 tons based on preliminary census data. This was an increase of 151,113 tons above shipments for the comparable months last year.

Newsprint

Production and shipments of newsprint in North America during July, 1955, amounted to 614,906 tons—an all-time July record—and to 624,081 tons, respectively, compared with corresponding totals of 603,057 tons and 581,037 tons in the same month of last year. Output in the United States was 124,501 tons—the largest July volume since 1926—and shipments were 121,679 tons while Canadian (including Newfoundland) production amounted to 490,405 tons and shipments to 502,402 tons.

Through the end of July this year United States mills turned out 185,614 tons or 27.5% more newsprint than in the first 7 months of 1954 while output in Canada also was 105,680 tons or 3.1% greater than in the corresponding period of last year, thus the continental increase totaled 291,294 tons or 7.1%.

Wastepaper

Eastern mills purchased more and consumed more wastepaper in July, 1955 than during any previous July in the last 10 years except 1951. While consumption in July was 30% below June of this year, it was only 5.3% below the tonnage of paperstock consumed by the mills of the East in July, 1951, the year that topped all previous ones for wastepaper consumption.

Mexico

Contracts for the building of the first newsprint mill in Mexico which will be one of the largest in South America, have been signed in Mexico City. The construction of the complete mill has been awarded to The Parsons & Whittemore Organization, New York, N. Y.

Site at Tuxtepec in Mexico where a newsprint mill will be erected by the Parsons & Whittemore Organization

The mill will be owned by Fabricas de Papel Tuxtepec S.A. de C.V., and will be located in Tuxtepec, State of Oaxaca, about 400 miles south of Mexico City. It will produce 33,000 short tons (or 30,000 metric tons) of newsprint a year, using Mexican pine as the raw material. This is about half of the total annual newsprint requirements of Mexico.

A further mill of similar size, to be located in the State of Michoacan, near the town of Uruapan, about 200 miles west of Mexico City, is contemplated.

What goes into a Dixie Cup?

Into a Dixie Cup goes a variety of hot and cold foods and drink... Cokes, soda and malteds in the flat bottom cold drink cup shown above for the younger set — in many other sizes and types, a wide selection of packaged foods for the home. In the relatively few years since the Dixie Cup Company created the first paper cup, the Dixie Cup has become a national institution.

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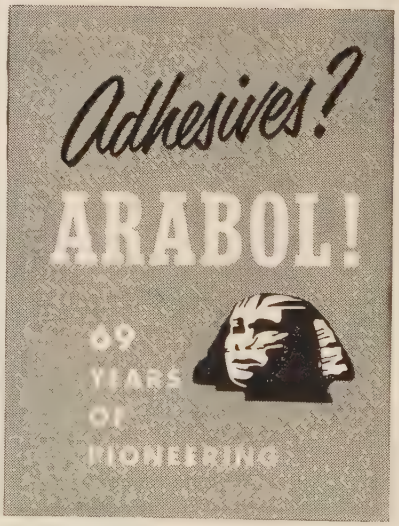

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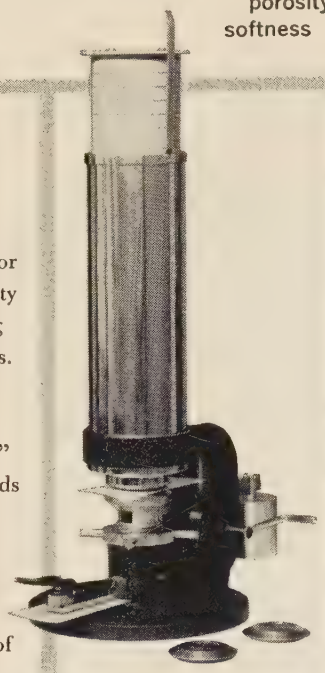

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The total cost of the Tuxtepec mill is estimated at about $12,000,000, and is expected to be in operation by the end of 1957. It is a joint venture of Mexican and American interests, with financial assistance of Nacional Financiera S.A., Mexico City, and the Bank of America N.T. & S.A., San Francisco.

Belgium

Expansion of the capacity of the paper industry has been undertaken both in the newsprint sector by Papeteries de Belgique, which hopes to be able to double its present capacity of around 57,000 metric tons during 1956, and in the kraft paper sector by Papeteries de Genval, which has invested in a machine capable of producing kraft paper starting from wood, understood to be the only one of its kind in Benelux.

Canada—Newfoundland

The government of Newfoundland appointed, in February, 1954, a Royal Commission on Forestry ". . . to examine into the forestry resources of the Province of Newfoundland with a view to their fullest utilization . . .," and to make recommendations on the efficient long term development of this premier source of provincial income.

The report places income derived from forest exploitation in first place among all sectors of the economy. Income from all woods operations and the pulp and paper industry amounted to $64,200,000 during 1951, 31.6% of the total income. Mining was second with $25,150,000 (12.3%) and fishing third with $20,000,000 (9.8%). The commission concludes that the pulp and paper industry should receive the main emphasis in government policy regarding the provincial forests, since it converts into newsprint and wood pulp the materials which those forests are naturally suited to produce. It recommends the strictest subordination of all other uses of the forest to the needs of the pulp and paper industry.

Newfoundland softwoods support the programs of two large pulp and paper companies. The larger, Bowater's Newfoundland Pulp and Paper Mills, Ltd., has its mill at Corner Brook, on the west side of the island. The Anglo-Newfoundland Development Co. mill is located at Grand Falls, on the Exploits River in north central Newfoundland. Both companies operate under provincial agreements very favorable to them financially. Among all Canadian pulp and paper companies only these two acquire pulpwood from public lands without payment of stumpage, the payment to the provincial government for trees on the stump to which title is vested in the province, though derived from the Crown.

A continuing forest reserve for long-term use in the production of newsprint and pulp depends upon proper balance of trees according to age. On the assumption that balsam fir matures in 60 years and black spruce in about 80 years, the commission has confirmed a serious imbalance in the distribution of pulpwood trees by age-class. With the added susceptibility of overage trees to insects and disease and the estimated unusable surplus of overmature timber, the Commission members regard the removal of all mature and overmature stands in 35 years as a pressing necessity.

Overage is not the only problem. It is estimated that the annual fire loss of softwood in Newfoundland is 75,000 cords. Blowdown and insects account for 10,000 more. Still, carrying out the proposal for removal of all presently mature and overage timber in the next 35 years will results in a surplus of 200,000 cords of pulpwood each year being made available above the foreseen needs of existing industry, plus 100,000 cords for export annually until 1990. To use this surplus, which otherwise would become overmature and be lost, a third mill is proposed. The suggestion that a group of small mills be erected is rejected on the grounds of excessive cost and inability of small mills to diversify their product.

The commission recommends that the operations of the

third mill not be confined to Crown lands, since they are too widely dispersed and the operations would be unattractive financially. The commission is attracted to the idea of a pooling or exchange of wood by the two companies and urges the government to acquire additional areas of forest land, by revestment of Crown lands from the companies (if not operated in accordance with the grant), and by acquisition agreement or expropriation when necessary in case of freeholds. The woods resources should be pooled, though this would not necessarily involve changes in the legal status of the holdings. By addition of necessary Crown lands areas, all three mills would obtain wood under one combined operation with a unified over-all working plan. The commission's views on liquidation of the old stand in 35 years depend in part on such a combined operation.

Labrador

The removal of excess old timber through the next 35 years will produce an annual domestic surplus of about 200,000 cords above foreseen drain. By 1990 the estimated annual drain (including unsalvable losses) will be 1,510,000 cords, as against annual growth potential of at least 1,470,000 cords annually. This future excess of drain over growth is to be limited by resorting to Labrador after 1990 as a supplementary source. Likewise, if expansion of the proposed third mill beyond recommended capacity within the next 35 years is contemplated Labrador will have to be considered as a reserve source of supply.

Cuba

The promoters selected central Progreso, near Cardenas, as the site for a new bagasse plant, because one of the "musts" for successful paper manufacture is to have abundant raw material close by, together with a short haul to tide-water and sufficient water for manufacturing purposes.

It will begin by producing newsprint in bobbins, of which Cuba imports around 30,000 tons per year; and possibilities for this commodity are enormous, since the world is asking for more and more newsprint and forest reserves dwindle, year by year.

Austria

Austrian per capita consumption of paper and cardboard in 1954 was about 31 kilograms (68 lb.), or 24% higher than in 1953, and 55% higher than in 1937, the last prewar year. This increase was largely the result of successful publicity drives aiming at an improvement of the Austrian standard of packaging.

These drives were started because of the extremely small use of paper for wrapping purposes in Austria, and met with unexpected response. Incoming orders increased sporadically and could, at times, not be met immediately. Secondly, the normalization of daily life, the higher educational level of the Austrian population, as well as the successful efforts of the export-minded paper converting industry, brought about a higher consumption of other paper grades, such as graphic paper, etc.

In spite of the remarkable increase of total paper and cardboard consumption in 1954, Austria—although being a paper producing country and one of Europe's most important paper exporters—still has one of the lowest per capita consumption rates in Europe. An increase of the present rate to the West European average of about 50 kg. per head of population would involve a reduction of Austrian paper and cardboard exports from presently 53 to approximately 20% of the production volume (50 kg., 110 lb.).

As compared with 1953, exports of pulp, paper, and cardboard, in terms of physical quantities, increased in 1954 by 20, 27, and 29% respectively. As in previous years, these products were shipped to about 80 countries all over the world. The most important customers of the Austrian paper

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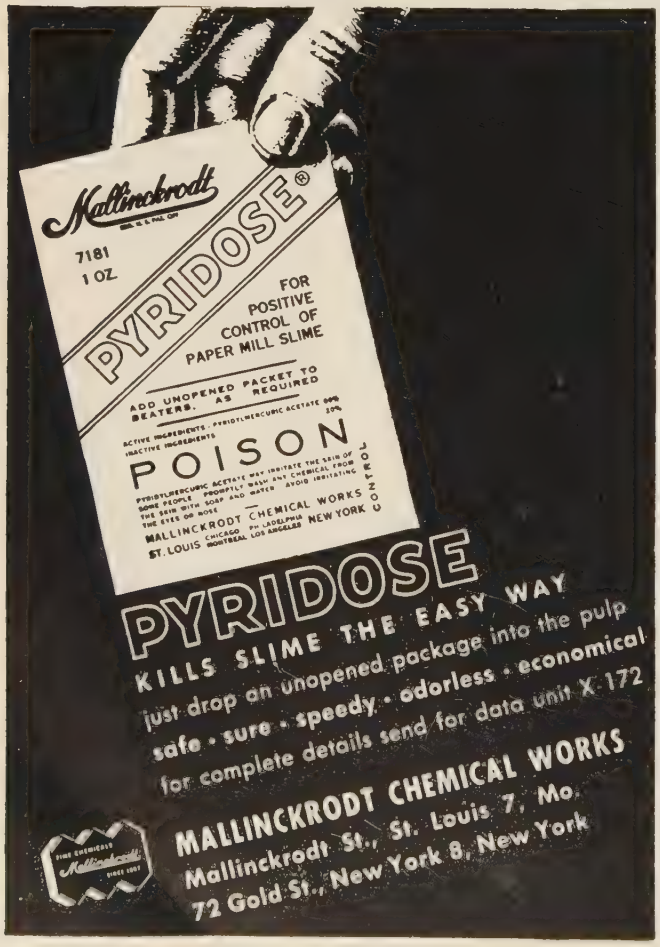
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industry—in the order of their importance—were West Germany, Italy, Great Britain, Switzerland, India, Indonesia, Trieste, Netherlands, Australia, France, Greece, Brazil, and Yugoslavia.

As in previous years no trade or barter agreement existed with Great Britain but business was maintained on the basis of a payment agreement. Although Great Britain usually restricts paper imports to small quantities of certain grades, Austria succeeded in expanding paper exports to this country in 1954 to 11,120 tons as compared with 4813 tons in 1953. Cardboard exports increased from 1189 tons to 1798 tons while pulp exports dropped from 3386 tons to 1839 tons.

Austria continued its policy of protecting her domestic industry and increased custom duties for a number of paper grades during 1954. Nevertheless, Austria increased her exports from 1427 tons in 1953 to 7501 tons (paper and cardboard only). At the end of the year, it became known that further increases of custom duties for products which are imported from Austria are planned for 1955.

No further expansion of capacity is envisaged for 1955. Investments will largely be limited to maintenance and repair works; new equipment will be installed only for wet-barking, effluent purification and power plants. The building of a small semichemical pulp mill (the first in Austria), which originally was planned to be completed in 1955, was not yet started at the time of reporting since the required credit was not yet granted by the government although the project was approved in principle. It is estimated that it will be started late this year. However, two more paper mills recently filed credit applications for the erection of semichemical pulp mills but of larger capacity. These projects are likely to be disapproved by the government because of the increase in wood requirements involved.

Italy

A good index to the state of the national economy, the paper industry in Italy has been stimulated since the war by an ever-rising level of business activity and income which has prompted a considerably wider use of paper products. As a matter of fact, domestic demand has been maintained at a rate in excess of the estimated annual increment of 50,000 tons in national productive capacity, with the result that the ratio of production to capacity has been steadily narrowed until it reached approximately 92% in 1954. Capacity is slated for further expansion during the current year from 1954's 800,000 tons to levels variously reported as between 850 and 900 thousand tons. Imports were contained to the point where they amounted to less than the increase alone in domestic output during the year, while exports, although considerably smaller in volume than imports, were nevertheless vigorously improved.

Increased production was made possible by continued supply of new equipment, improved manufacturing techniques and additional plants. As of August 31, 1954, there were 320 paper mills in Italy, of which only 11 were inactive; these figures compare with 294 mills at year's end in 1953 of which 13 were inactive.

Every branch of the Italian paper and cardboard industry bettered its production during 1954, in contrast to the prior year when wrapping paper output had declined. Mention, however, should be made of the notable advance scored by the catch-all sector labelled "other types of paper" which amounted to 126,000 tons in contrast to 101.3 thousand tons in 1953. This sector includes "straw" paper which accounted for 76.3 thousand tons of the 1954 total. In addition to straw paper products, numerous miscellaneous articles—to an increasingly greater extent innovations encouraged by a rising standard of living—have been placed on the market. Among these items may be listed waxed paper, cardboard and paper plates, silvered paper plates and trays, paper cups, paper napkins, sanitary paper, etc., all of which are not in

every instance new to the local market but are appearing in better quality, quantity, and styles, in response to a fairly new and insistent demand.

The theoretical per capita consumption of paper products (based on a population of 48 million) once again was intensified, amounting to 16.1 kilograms (35.4 lb.) as contrasted to 14.8 (32.6 lb.) in 1953. While this level is still considerably below that of other western nations, it is important to stress that Italy's rate of advance during these past several years has been well in excess of the general world average if production figures are taken as a guide.

Demand for paper products in Italy during 1954 was in most respects the result of a rising standard of living which not only expanded the base of the potential buying public, but also augmented the variety of its requirements. The intensification in over-all industrial output has also created a wider need for paper and cardboard products, especially for packaging. The gradual evolution of the substandard Italian southlands must likewise be accorded its share in the accelerated demand for paper. Furthermore, in the wake of higher income have come advances in sanitation and more exacting municipal regulations for the packaging of food, developments which are being encouraged by paper manufacturers.

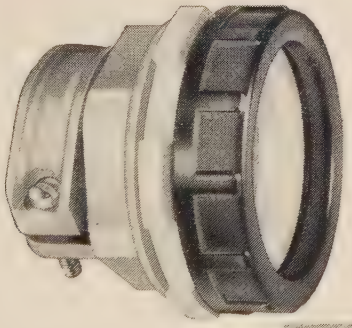
Once again, the increased need for pulp was satisfied chiefly by a greater volume of imports, which were enhanced 25% during 1954 to a record 231,554 tons in contrast to a national production of 250,878 tons (up by only approximately 5000 tons from the preceding year's output). In other words, imported pulp now accounts for 48% of the quantities consumed by the local paper industry.

The entire increase was represented by chemical pulp (cellulose), of which roughly two thirds was imported, as compared with mechanical pulp which is mostly obtained from domestic sources. The reason for this interesting development is not entirely clear, since both types of pulp are considerably cheaper when imported. Trade sources consulted, however, explain that, in general, mechanical pulp is derived from poplar and other timber which are in reasonably plentiful supply in this country and of fair quality, so that many of the leading paper mills produce their own requirements of this commodity. The reverse, however, is reportedly true of chemical pulp which is processed from timber of lower quality in Italy and is therefore less desirable than that available in Scandinavia, Germany, and Austria. As a result, Italian paper mills are said to prefer foreign cellulose, and increasing paper production needs have resulted in a very notable expansion in such imports from a level of 119,953 tons in 1952 to 214,277 tons in 1954. This preference is expected to continue, so that domestic cellulose productive capacity is maintained mostly as a hedge against unfavorable developments in international price and supply.

The heavy growth of imports of finished paper products during 1953 was arrested in the following year, when a slight actual drop (the first recorded since 1949) took place, the total amounting to 54,801 tons in contrast to 55,979 tons in 1953. Although local trade sources still complain of the serious inroads of foreign competitors, it is worth while to place the situation into perspective by noting that the ratio of imports to national output was only 7.4%.

Declines were registered in every category, including newsprint, with the sole exception of kraft paper and cardboard. Moreover, last year's well-publicized charges of "dumping" by Austria and the Soviet bloc nations upon the Italian market have been quietly dropped this year. Nonetheless, the association maintains that the industry is seriously menaced by imports, liberalized since 1952 (except from the dollar area), and unfailingly renews its requests for higher tariff protection, or deliberalization.

The success of the Italian paper producers in curbing the



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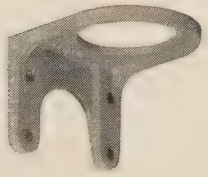

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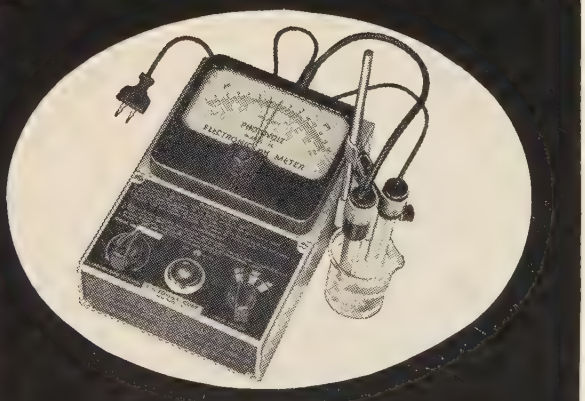

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previous year's relatively heavy expansion in imports—up from 1952's 27,774 tons to 55,979 tons the following year—is officially ascribed entirely to more competitive Italian prices. The undoubted assistance afforded by the 2% increase in duties, although admittedly limited, is not mentioned. Nevertheless, it is true that while quotations on the domestic market rose by only 1.9% on the average, the general value of imported paper products advanced 5.4%.

The principal suppliers of finished products were, as usual, Germany, Austria, and Scandinavia. Imports from the United States were augmented from 1953's extremely low mark of 996 tons to 1553 tons of paper and cardboard items. This slight increase is not significant in relation to the total quantity of imports; moreover, the United States has never been an important supplier to Italy in this line because of strong European competition and difficulties in the release of dollar exchange. Nevertheless, there is reported to be a potential, if limited, market for United States paper goods, provided prices are favorable, quality high, and of technically more advanced types, particularly if not easily procurable elsewhere.

Although exports play a minor role in the Italian paper products industry, a very notable upsurge in the volume of exports occurred during the year under review, rising from 12,224 tons in 1953 to 19,412 tons. This development has been especially welcome since it reversed a sharply downward trend recorded since 1951, and has been continued into 1955, with exports for the first 3 months registered at double the volume of those of the corresponding period of the last year, at an annual rate close to 1952's.

The principal reason for this satisfactory performance is the steep cut in export prices which the Paper Association estimates at 10%. Lower prices presumably resulted in substantially bigger shipments to the United Kingdom, The Netherlands, and Syria.

An action of prime significance to the industry was undertaken by the Italian government when it approved, on July 31, 1954 (Law No. 570), the reimbursement of 2% of the I.G.E. (general transactions tax) on all exports of paper and cardboard products. However, this measure, enacted in response to the strong pressure of the industry for financial assistance in counteracting foreign competition abroad, was considerably vitiated, in its viewpoint, by the concurrent imposition of a 1% duty levied on all pulp imports. Moreover, since the I.G.E. tax is reported to vary between 3.88 to 5.19% the much sought for aid is alleged to be more illusory than real. At the same time, the government introduced a 2% duty on all paper and cardboard imports (a so-called "imposta di conguaglio"). Both the 2% impost on finished products and the 1% duty on raw material supplies were, curiously enough, justified under the guise of financing the reimbursement of a tax, which, however, is presumably collected, and which itself ranges from close to 4 to over 5%. Taking the government's reasoning at face value, it would appear that the state has simply added to its revenue by a measure which will probably raise the cost of both the imported and domestic product, but provide little financial succor to the industry on foreign markets. Its chief value seems to be the unstated one of protectionism which increases the tariff on imported paper articles by 2%.

Netherlands

Production in the pulp and paper industry rose by about 10% over 1953 mainly due to an increase of approximately 16% in the production of wrapping paper. Exports, however, declined, but this was more than offset by steadily increasing domestic sales. The large domestic demand also required a further increase in the already high level of imports. The price level for pulp continued to increase considerably throughout the year but there was no significant corresponding increase in price levels of paper products because of the existence of a price arrangement between pro-

ducers and wholesalers. In addition, the high level of sales made it possible to avoid a revision of the price arrangement. The outlook is promising because of ever-increasing world demand. A new paper plant with a capacity of 15,000 tons will be opened this year and existing plants are also increasing their productive capacity.

Norway

A development of far-reaching significance for the Norwegian pulp and paper industry occurred toward the end of December, 1954, when the firm A/S Union, Norway's leading manufacturer of cellulose and newsprint, produced newsprint from sulphite pulp made from pine. It was the first "pine sulphite" pulp (and consequently the first newsprint made from "pine sulphite" pulp) ever manufactured in Norway, and among the first produced anywhere in the world.

The significance of this development is obvious. The Norwegian industry has for several years been in the throes of a mounting timber crisis. In order to preserve its dwindling timber reserves it has been necessary for Norway to restrict the size of its annual timber cut at a time when the raw material requirements of the domestic pulp industry have been increasing steadily. In 1954, for example, only about 3.5 million cubic meters of the restricted 1953–54 timber cut were allocated to the pulp mills; during the same period, the Norwegian wood pulp industry consumed an estimated 4.8 million cubic meters of pulpwood, while producing an all-time record amount of chemical and mechanical pulp. Stocks of pulpwood, already drastically reduced during 1953, were reduced even further, and it was necessary for Norway to import at least 500,000 cubic meters of pulpwood from Finland and Sweden at considerable expense. The rest of the deficit was made up in the increased utilization of small-dimensioned timber, logging waste, and even deciduous wood for the production of wood pulp, and in the rationalization of many industrial operations. Heretofore the pulp industry has been dependent largely on spruce timber, of which the domestic supply is limited, while the pine forests have not been exploited to their fullest capabilities. In Norway, pine responds more favorably to forest regeneration than spruce and can be grown on poorer soil. If full use can be made of the "pine sulphite" process in Norway, more spruce can be made available to the rapidly-expanding mechanical pulp industry, imports of pulpwood can be correspondingly reduced, a new element of rationalization can be introduced in forestry, and increased quantities of pine can be utilized in the production of valuable finished goods to the benefit of the Norwegion economy.

According to published information, A/S Union intends to convert its Skien chemical pulp plant entirely to the production of sulphite pulp from pine in the second stage of reconstruction now under way. The plant will be designed to convert 125,000 cubic meters of pine annually, freeing an equal quantity of spruce for conversion to mechanical pulp at the company's grinding mill in Skien. The above-mentioned quantity of pine timber is reported to be available in surrounding Telemark county and the promise of its procurement has been welcomed enthusiastically by the forest-owners in that area. A/S Union is also reported to be considering the acquisition of a new paper machine capable of producing 50,000 metric tons of newsprint per year to be devoted to the production of paper from its pine sulphite pulp. (For the time being the company is using one of its other paper machines part time in the production of newsprint from pine sulphite.) The cost of such a machine is estimated at between 40 ($5,600,000) and 50 ($7,000,000) million kroner. The magnitude of such a decision is illustrated by the fact that the Norwegian paper industry has been able to afford only two new paper machines since World War II. The addition of a 50,000-ton newsprint machine would increase the newsprint capacity of A/S Union by about 50%.

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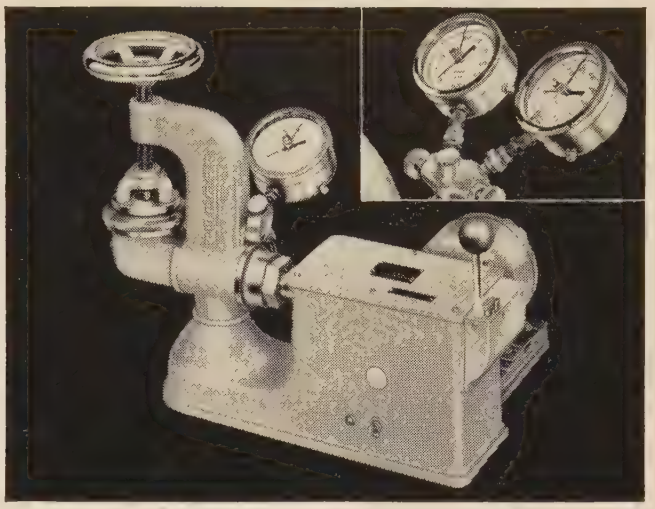

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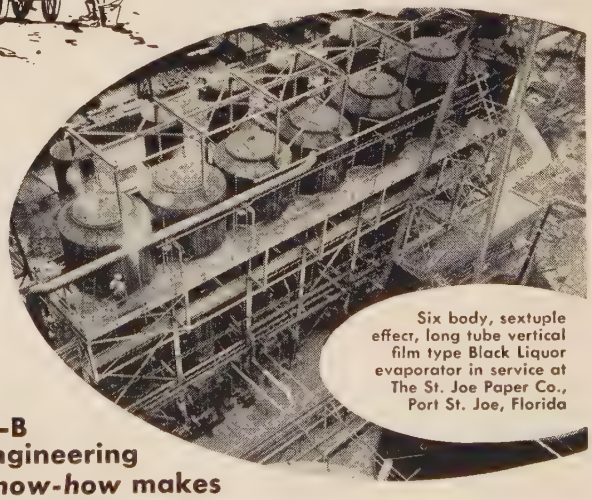

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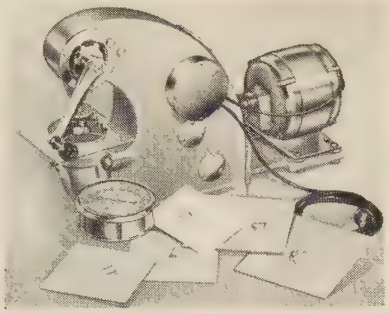

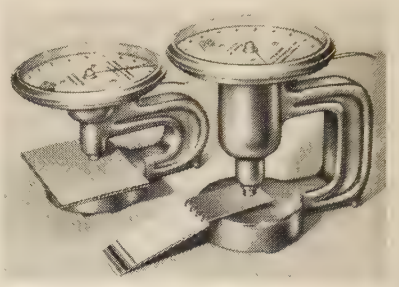

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South Africa

The growth of the Union's pulp and paper industry has been paralleled in recent years by an expansion in the country's paper and packaging requirements. As in the United States, the production, sale, and distribution of merchandise is requiring increased use of containers, wrapping paper, and packaging materials, and imports still account for the majority of the paper consumed in the Union. The principal source of supply for kraft paper is Sweden. Newsprint is not produced in the Union of South Africa, the country's current annual requirement of 57,000 short tons being supplied principally from Canada, the United Kingdom, and Norway.

The Union's first pulp mill was established in 1938. Until 1949 soda pulp formed the bulk of the total pulp produced; in that year a new plant commenced production of mechanical, defibrated, and exploded pulps. In the following year production of bleached sulphite pulp was started and by 1951 total pulp production had reached a rate of 38,000 tons per annum. Further additions in recent years have brought domestic woodpulp production to a figure of 100,000 tons per annum.

The most notable recent addition to South African pulp capacity is the Tugela River mill of South African Pulp and Paper Industries, Ltd., financed partially by the Government's Industrial Development Corporation with a minor financial interest by Wiggins Teape and Co., Ltd., of London. The Tugela mill, which commenced operation in 1954, has a rated capacity of 30,000 tons of unbleached pulp. The corrugated box industry will use the bulk of the mill's output, but wrapping, bag, and sack paper is also being produced. Meanwhile, the company completed an extension during 1954 of its Enstra mill, near Springs, Transvaal, where current annual production consists of 30,000 tons of bleached pulp, producing printing, writing, and duplicating papers.

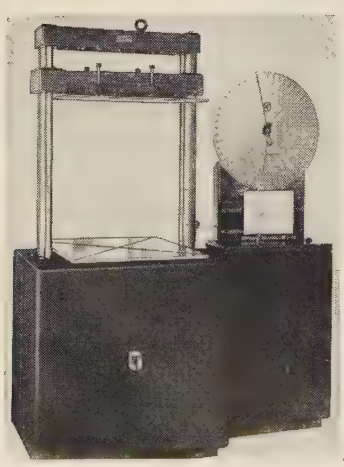
Sweden

The competition in Europe from North American pulp producers, which previously had caused such grave concern in Swedish trade circles, seems not to have had any price-depressing effect in the European market so far. The consensus in Swedish industry circles seems to be that the current high rate of European paper mill operations has created a pulp demand large enough to absorb all the Swedish pulp that becomes available for export this year in addition to the tonnages that North America may be expected to ship to Europe in 1955.

Large-scale production and shipments also highlighted developments in the Swedish paper and board industry during May. The outputs of most mills are reported to be booked up for months ahead but the shortage of skilled labor is said to be preventing full utilization of productive facilities. Sweden's paper exports were maintained at a high level in May. In that month the market outlook improved further, following the announcement by the British Board of Trade of increased import quotas for several types of paper and board during the second half of 1955 and a promise of the French Government to consider a reduction in the import tariff rate for paper from 15 to 7% ad valorem.

West Berlin

No paper mill existed in Berlin before the war. The large quantities of waste paper available in West Berlin could only be utilized in the Federal Republic of Germany or in the Soviet-occupied Zone when included in the annual Interzonal Trade Agreements. Therefore, it was of vital importance that the Gottwald & Co., Karton-und Papierfabrik GmbH should be erected, the owners of which are refugees from Silesia in the Soviet-occupied Zone. The firm began full operation during the early part of August 1954. Production



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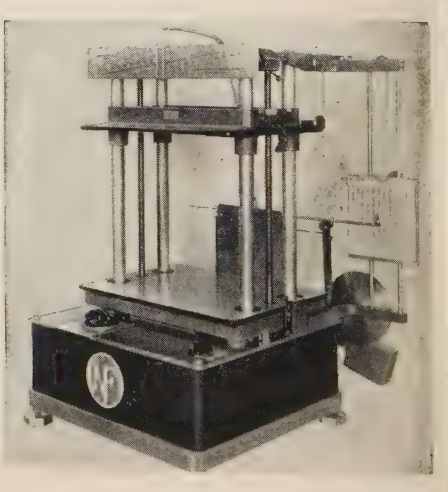

today, derived largely from the re-pulping of waste paper, amounts to 30 to 40 tons daily of wrapping paper and about 40 to 50 tons daily of cardboard. The Gottwald paper mill uses exclusively waste paper and newsprint for the production of ordinary wrapping paper of various weights and colors (other than white). New cellulose from Scandinavia is only used up to 15% for the finer grades of wrapping.

Canada

The question of seven-day operations in Eastern Canadian newsprint mills appears to have been shelved for this year. Most of the mills have signed new contracts with the International Brotherhood of Pulp, Sulphite, and Paper Mill Workers, but none call for a seven-day week. The question of continuous operation was raised during negotiations with several companies.

Canadian paper production data for 1954 were as follows: production, 7,642,000 tons; imports, 150,000 tons; exports, 5,661,000 tons; apparent consumption, 2,131,000 tons; per capita consumption, 280.3 lb.

The 500-ton pulp mill being constructed in Alberta by St. Regis Paper Co. and North Canadian Oils, Ltd., is scheduled for completion early in 1957 at a cost of $33.5 million. The mill is to be powered by gas piped 136 miles through a 10-in. line.

Great Britain

The British government's control over the number of pages the country's newspapers may print will end in March, 1956, after more than 15 years of rationing.

Michigan

Backed by substantial help from forest industries, the Lake States forest survey, directed by the Lake States Forest Experiment Station and the Michigan Department of Conservation is well along with field work in Michigan. Field crews expect to complete their upper peninsula assignments by December, 1955, and results of the inventory should be summarized by early spring. Three reports for four counties have already been released. Private companies which have contributed financially to expedite the Upper Peninsula survey include:

Kimberly-Clark of Michigan, Inc., Neenah, Wis.
Escanaba Paper Co., Escanaba, Mich.
Badger Paper Mills, Inc., Peshtigo, Wis.
Manistique Pulp & Paper Co., Manistique, Mich.
Marathon Corporation, Menasha, Wis.
Charmin Paper Mills Co., Green Bay, Wis.
Green Bay Paper & Pulp Co., Green Bay, Wis.
Scott Paper Co., Detroit, Mich.
Kingsford Chemical Co., Iron Mountain, Mich.
Peterson Brothers, Carney, Mich.
Larson Brothers, Rock, Mich.
Michigan Pole & Tie Co., Newberry, Mich.
F. P. Furlong Co., Newberry, Mich.
Barrett Logging Co., Newberry, Mich.
Russell Watson, Manistique, Mich.

In the lower peninsula, where field work was completed last fall, three reports covering 30 counties have been published. In this part of the state the American Box Board Co. has participated in a substantial way since 1950, according to Mr. Dickerman.

The survey, when completed, is expected to provide a basis for planning improved utilization of the forest resource of Michigan and may point the way for developing forest industries in certain areas.

Missouri

Kansas City affords a good potential location for a mill producing container board and boxboard for the manufacture of paperboard boxes, according to a study completed recently by the Midwest Research Institute, Kansas City, Mo.

A thorough market study conducted in the Kansas City

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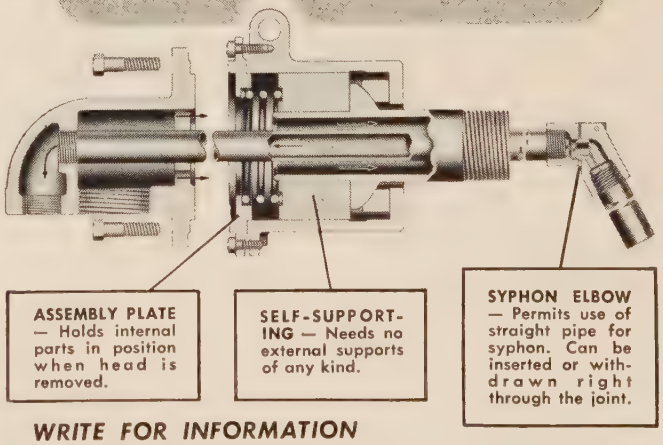
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area by the Midwest staff revealed that present container board and boxboard mills are producing only about 400 tons per day, while demand for such products is approximately 1200 tons per day. Furthermore, it is pointed out that the demand for boxes may be expected to keep pace with the swiftly increasing industrial, wholesale, and retail activities of the area.

Pennsylvania

Pennsylvania's Clean Streams program has greatly improved the Brandywine Creek through the installation of waste treatment facilities in plants and municipalities on the stream. Facilities are in operation at the paper mills of S. Austin Bicking Co., Downingtown Paper Co., Eagle Paper Co., The General Paper Co., and the Modena Paper Co.

Waste Utilization

Of each tree felled in the forest, less than 50% ever reaches the market. However, recent advances in waste utilization are steadily raising the percentage of usable fiber. Forty per cent of the pulp produced in the Northwest is obtained from sawmill residues, the hard board industry is using increasing quantities of residues and low-grade timber, and chemicals, soil improvers, and fuel briquettes are being made from sawdust.

Forest Products Industry

Forest products ranks among United States' six largest manufacturing industries, according to the latest, 1952, Bureau of Census statistics. The others are food, clothing, metal products, machinery, and transportation. Its more than 40,000 establishments, exclusive of an additional estimated 60,000 small sawmills scattered throughout the length and breadth of the land, ranks it first in total number of plants. It ranks fifth in persons employed, 1,557,000; and sixth in value added by manufacture, over $9 billion.

Reducing Machine Room Noise

The paper industry may be on the verge of discovering better means of eliminating machine room noise.

A new suction roll "silencer" is being tested on one of Canadian International Paper Co.'s biggest newsprint machines at Gatineau, Que.

Canadian researchers are convinced that paper can be made efficiently on a silencer-equipped open machine. The actual design by the National Research Council in Ottawa was not announced, pending patents, but it already had proved successful on a laboratory model suction roll. The commercial size installation is one of four Gatineau 271½-in. fourdriniers. The mill has two smaller machines, also.

Another type of silencer applicable only to machines equipped with vacuum transfer and tested on another Canadian machine with sheet running into the pit, was reportedly highly successful. It was to have a mill trial at Quebec North Shore Paper Co., Baie Comeau, on a high-speed vacuum-transfer equipped couch.

A few newsprint companies such as Powell River Co. have been making independent tests to supplement the project undertaken by National Research Council at Ottawa.

The boxlike structure which houses the silencer apparatus is a relatively small object installed in the couch and while it is said to be a long way from the complete answer to the problem of machine room noise, engineers say it is promising.

Several machine manufacturers have attacked this problem. Engineers at Beloit Iron Works, for example, have used latest recording and experimental instrumentation both in extensive laboratory setups and in actual mill situations.

A primary consideration was to determine the exact nature of the sound and to completely explore the fundamental physics of its generation. This has led to several successful mill corrections.

Development work on models at Beloit and on rolls running in the field has proved that noise energy can be reduced on the order of 6 to 20 decibels, which in some cases reduces the sound beneath the level of background noise.

Beloit engineers predicted that in the near future machine room noise can be effectively controlled.

Dimensional Stability in Paper

What is dimensional stability (or instability, if you like); why does it occur and what can you, the printer and buyer of printing, do about it? Unfortunately, only to the first of these questions can we give a definite answer.

Dimensional stability (the potential changes which can take place in the sizes and shapes of paper) concerns stretch, strinkage, curl, creasing and other related bugbears, which are usually nobody's fault and always everybody's headache. They are, to date, one of the least understood of paper problems, from the standpoint of all concerned. Much progress is being made, however, and the general directives which follow are the result of continuing study and experimentation.

Probably the most significant advance so far is the basic recognition, by the printer, advertiser, and papermaker alike. that a very real problem does exist. If they were dealing with tin plate they would have little or no trouble. But paper is different. Paper is an extremely delicate, easily affected, "live" subject. In fact, it is more delicate, susceptible, and alive than many people realize. "Fiber and water," held together in varying ratios by varying finishing methods—this basically, is paper. And its fibers, particularly, are extremely "emotional." They will stretch (usually refusing to return completely to their original dimensions), they will expand and contract (quite often with disastrous results), and they are extremely subject to changes in temperature, moisture, and so on. The gradual acceptance of these inevitabilities and the strides being made to obviate them are doing much to cut down on production and quality losses, through paper changes.

What causes paper to get out of shape; to stretch, shrink, curl, crease, and so on? There are five main reasons:

(a) Moisture
(b) Temperature
(c) Roll stretch
(d) Ink tack
(e) Excess fountain water (lithography)

The changes due to these factors become more obvious—visible to the eye, disturbing to quality and production—in inverse ratio to the paper's weight. The lighter the paper, the more drastic are the results.

It might be contended that if conditions for making paper and using that paper could be the same, then we would have no troubles. But the fact is that even apparently similar conditions aren't always so, nor do they produce similar results. For example: papermakers make 50% relative humidity paper but what is 50% R. H.? At 70° it is one thing, at sixty another, and at fifty it is different again. It has been established, however, the maximum results are achieved from a sheet of paper at 50% relative humidity and 70°F.

What about roll stretch? Paper technicians endeavor to meet required specifications, but every papermaker knows how temperamental a paper machine can be. It is an accepted fact that even different runs of the same paper often produce varying dimensional changes. An apparently hard roll, for instance, may be too hard in one spot stretching the paper at that point. A very tacky ink can stretch a sheet both overall and/or in localized areas. The latter may be a cause of doubling on multicolor offset presses and, too, is much more admissible of definition than it is of cure or control.

Quite naturally you are saying: "What is the answer to all this? We know the causes (or at least some of them) and are as sympathetic as can be expected. But we want to know

what to do about it." This is a fair and justifiable attitude and it would be gratifying if the answers were as simple. One of them is, perhaps. Our commonsense will probably help as much as anything. Milk will go bad in heat; paper can too. You can die of thirst; paper can too. Your wife fights bulges in the wrong places; paper does the same thing. So, let's remember six things:

(1) Paper, as we have already seen, is a very fragile medium. Too many people think we cut down a tree, beat it up a bit, and out comes paper. No! Papermaking is still an art, now carried on by machine instead of by hand, as originally. And, strangely enough, it was the very introduction of the papermaking machine that really sparked most of our present-day problems. Handmade paper followed size and thickness limitations which were irregular; had very few finishes and never heard of grading. Modern papermaking has specialized and specializing usually tends to restrict adaptability.

(2) Paper is essentially fiber; fiber which has to expand or contract, usually in the cross machine direction. Then, as a result of the factors which affect paper dimensionally, fibers fatten or shrink—and they do it in all directions, mainly cross machine. The puzzle of the papermaker, therefore, is to maintain paper uniformity despite the possibilities of this situation.

(3) Think of paper as a bimetallic strip. Because it must be carried on felt and wire, there is always a slight variation from one side of the paper to the other. Even calendering and coating do not wholly eliminate this.

(4) Continuing investigations have shown that the same answer doesn't always meet the same question, probably because of the many uncontrollable variables of paper, press, ink, and pressroom operation.

(5) Regular checking, too, reveals the remarkable fact that some pressrooms vary all the way from 15 to 80% humidity, within the seasons. This is a major factor, in itself.

(6) Finally, your paper man stands ready and willing to advise and help, at all times. Humidity control, press conditions, fanning, hanging, and similar things, are matters with which the printer should be completely conversant and to which the buyer should be truly sympathetic. The continuing efforts by paper technicians to obviate dimensional instability in paper, adds to their desires to serve in this matter.

—by F. E. Masterman in *Provincial's Paper*, March-April, 1955.

Multicolor by Overprinting Using Flexographic Inks

The principle of using the three primary colors, red, yellow, and blue to produce an equal number of secondary colors, orange, green, and purple, plus one additional tertiary color, brown, has been well recognized in the graphic arts field for many years. This principle coupled with the halftone plate has expanded the color range in a continuous pattern from light yellow to dark brown by using only three color units on letterpress, gravure, and offset presses. Additional shadow effects are usually obtained by using black as a fourth color. Plates for this type of work are generally prepared by photographing any subject through a series of red, yellow, and blue filters, and then exposing a sensitized plate to the color separation negatives through a suitable screen pitched at various angles.

The combination of these two principles, that is, mixing of color and the use of halftone dots, permits the letterpress, gravure, and offset processes to produce photograph-like effects with almost continuous tones from one end of the spectrum to the other. Although these principles have been used for many years, the benefits gained by overprinting when using solid, line, or stiple plates in lieu of halftone plates have not been well recognized until recent discussions initiated by Donald E. Cooke of the John C. Winston Co. He has pointed out in a series of articles that the use of the three primary colors plus any additional color including black can result in seven to fifteen colors depending on whether three or four colors are used in combination.

This concept should have great importance to the flexographic printer because, although the use of halftone work is growing in this industry, the majority of printing is still done from line or stiple plates.

It should be recognized, however, that when applying the principles of multicolor by overprinting to three-color line work, only seven specific colors are possible and no tonal variation within any specific hue can be attained. By amplification, this means that only one yellow, orange, red, green, etc. can be produced and not several shades of these primary or secondary colors. Despite this apparent restriction, the finer types of line drawing, such as fine pen and ink, and various stippled techniques such as the use of litho crayons on grained surfaces can achieve tonal effects similar to halftone, but with less of the mechanical appearance of a coarse halftone screen.

If a printer of opaque stock, such as paper or boxboard, is equipped with a four-color press, it is possible to obtain interesting designs by using the three primary colors, red, yellow, and blue, and selecting a color other than black as the fourth one. For instance, a fruit bowl design can be beautifully highlighted by using dark purple as the fourth color, thereby emphasizing the tonal values of grapes, apples, cherries, plums, and other deep purple fruits. If an outdoor scene is used, it is possible to obtain startling shadow effects throughout the foliage by using a second darker shade of green, deeper than that which is obtained by overprinting yellow with blue.

When printing cellophane, cellulose acetate, polyethylene, or other transparent films, it is recommended that white be used to underlay the job. The remaining three fountains can be supplied with yellow, red, and blue thereby yielding a "seven-color-job" if the principles of multicolor by overprinting are utilized.

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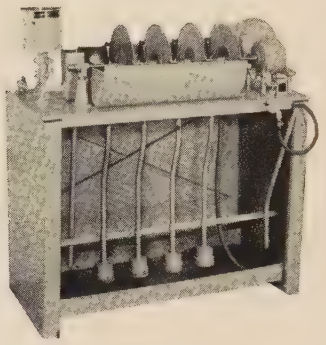

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Although the use of primary colors of yellow, red, and blue, plus black, green blue, or purple will probably perform best for the majority of overprinting work, other three and four color combinations can be selected to produce unusual and pleasing effects. Mr. Cooke in his forthcoming book, "Color by Overprinting," for which Bensing Bros. & Deeney performed the ink research, demonstrates this point with more than 50 illustrations.

Flexography is a natural field for the expansion of the concept of multicolor by overprinting because of the wide latitude which the inkmaker has in formulating the flexographic product. The ink can be made completely transparent, or completely opaque, depending upon the desire and need of the specific design at hand. Running speeds between 250 and 500 f.p.m. can easily be obtained by using flexographic inks and registration techniques which assure proper control of this function are available from most press manufacturers.

When requesting inks for multicolor jobs it is a wise procedure to submit to your inkmaker the progressive proofs of the design in question, as well as a sample of the stock to be printed. It is also important that the proofs of the progressives be submitted on the stock to be printed. Variation in the color and quality of the stock will most assuredly affect the color and quality of the finished product.

Paper printers should not overlook the possibility of obtaining additional tonal effects by using colored paper as the starting point. A light pastel colored paper, coupled with the multicolor effect obtained by superimposing yellow, blue, and red, and possibly black or purple can result in eye-appealing effects which are sure to startle and awaken the industry.

Of further important consideration is the price of most printing, which is often geared to the number of colors printed on the carton or bag. The use of a technique whereby the number of colors can be expanded without additional investment in equipment is certainly an important item in the pricing of bags, paper, and cartons printed using this procedure.

The use of metallic pigmented colors in which small quantities of aluminum powder are dispersed along with the transparent colors such as transparent yellow, blue, and red is another area where additional design innovations can be promoted on transparent and opaque stocks.

Finally, the use of only three colors to produce seven, gives most flexographic printers of paper who are equipped with four color presses the latitude of applying a high gloss over print lacquer in the fourth station. This premium package is sure to demand a higher price, particularly if designed to take advantage of the splash of color obtainable by overprinting.

This concept of overprinting is particularly important to the boxboard field where flexographic printing is gaining tremendous popularity due to the inherent qualities of this solvent-type ink. When flexographic inks are used to print boxboard, speeds of 375 f.p.m. can be attained with ease and the resultant prints fed directly to dye cutters, formers, creasers, laminators, or other secondary converting operations. It is possible to increase the speed of printing by equipping the press with heating facilities in the form of high velocity hot air ovens or flame impingement gas burners. The resultant prints are brilliant, light fast, and rubproof.

Furthermore, the convertor using the flexographic process to print boxboard has a great advantage because of the wide range of inks which are available to him before performing this function. Translustro dyestuff inks whose low viscosity and high color strength permit them to produce the finest of all flexographic details are recommended where commercial lightfastness is acceptable. Flexokraft inks which are a combination of dye and pigment inks are recommended where the high color strength of dyes can be fortified with the lightfastness which is characteristic of the pigment portion of this product. One hundred per cent pigmented Excellopake inks are recommended for use on boxboard where the ultimate in lightfastness and gloss are desired. Velvatex inks are recommended for printing boxboard where a soft matte finish will contribute to the design of the box. These 100% pigment formulations are available in alkali and soap-fast formulas which make them extremely suitable for printing detergent and soap cartons. Velvatex inks are nonthermoplastic, and are suitable for subsequent hot-creasing, dye cutting, or even corrugation.

Finally, Hydrotone and Hydrotex inks which are water dilutable in nature can be used to print boxboard and paper where the economies of this type product are desired, along with the good wet and dry rub which these inks produce. All the flexographic inks in the aforementioned categories can be used to package food products because they are odorless and nonbleeding in fats, waxes, oils, and greases. This characteristic permits the resultant carton to be waxed, glue laminated, or overlacquered with a suitable high gloss, protective lacquer. These lacquers are available where increased scuff resistance, gloss, and improved slip qualities are required by the end use of the carton.

In conclusion, the possibility of using this straightforward concept to double or triple the number of hues obtainable from three and four-color presses should not be overlooked by any progressive flexographic printer. It requires no additional investment, personnel training, or techniques not now available to all printers, and can result in outstanding jobs whose color latitude and design quality cannot help but add another laurel to flexography and make its expansion the envy of the graphic arts industry.

—from a Special Report by Bensing Bros. and Deeney, Philadelphia, Pa.

Simplified Fire Extinguishers

Have you ever tried to use a fire extinguisher only to find that it was designed for a different kind of fire? Or discovered that a particular extinguisher operated differently from any that you had used before? Or breathed the deadly fumes generated in using some extinguishers? Or spilled acid on your clothing while servicing another type of extinguisher? All of these mishaps, and worse, have happened to many people.

Most fires could be stopped in their early stages by judicious use of a hand fire extinguisher. Prompt action by an alert employee could save his job and his employer's business. It is estimated that nearly a third of all fires—more than two thirds of fires in industry, are extinguished with hand-operated fire extinguishers.

This record is impressive when considered by itself. In relation to the annual toll of fire, it loses much of its significance.

Our direct fire losses today amount to over a billion dollars a year and indirect losses are several times that figure. Some 12,000 people lose their lives in fire and thousands more are severely burned each year. Every possible means of reducing these fire losses is worth considering. Simplification of the design of fire extinguishers is one avenue of approach that would be worthwhile.

There are eight types of fire extinguishers commonly sold today. Five can be used on fires in ordinary combustibles such as wood, cloth, paper, and rubbish. Five are available for use on burning oils, greases, and other flammable liquids. There are three types available for fires involving electrical equipment.

Some extinguishers can be used on two different kinds of fire. None can be used successfully on all three.

Confusion Confounded

Among the eight basic types of extinguishers are a multi-

tude of operating techniques. One recent publication of a recognized laboratory illustrates four methods of actuating carbon dioxide extinguishers and five methods for operating dry-chemical extinguishers. Here indeed is confusion confounded. Is it any wonder that many fires get out of hand while the bewildered worker tries to figure out the method of operating a particular extinguisher.

Recognizing the value of present-day fire extinguishers, it is believed their utility could be measurably increased if the eight types could be reduced in number and the operating mechanism standardized.

Let us explore the possibility of reducing the number of fire extinguishers by examining well-established characteristics of each. Extinguishers for fires in ordinary combustibles are a good starting point.

The common soda-acid extinguisher is probably the oldest and most widely used. This unit, however, must be inverted so that the sulphuric acid will mix with the bicarbonate of soda solution to generate gas to expel the mixture. It must be emptied, washed, and recharged each year using care to avoid spilling the acid. It is good only for fires in ordinary combustibles.

Foam extinguishers operate much as the soda-acid type but with aluminum sulphate in place of sulphuric acid and a stabilizer is added. The same objections to method of operation and maintenance apply plus the fact that the sticky foam solution is hard to clean up after the fire is extinguished. This extinguisher is suitable for use on both combustible and flammable liquid fires. Since the solution is conductive, it should never be used on fires involving electric equipment.

Another extinguisher is the "loaded stream" type. Here a proprietary liquid is expelled by gas from a pressurized cylinder. There is a wide divergence of opinion on the merits of this extinguisher and it is not recognized by one of the two large laboratories engaged in testing and approving fire extinguishers. It also can be used on combustible and oil fires but not on fires in electric equipment.

Another common type is the water pump tank. For outdoor work—on grass, brush, or trash fires—this is unexcelled because it can be refilled quickly and kept in constant operation. However, the pump tank requires more maintenance than many types and is not convenient for use on indoor fires.

The charged water extinguisher uses pressurized gas or a small gas cylinder inside the body of the unit and plain water. This type of extinguisher is easy to use, clean and simple to maintain. Again, it is limited to use on fires involving combustibles.

Simplicity Is Possible

From a purely functional point of view, the number of extinguishers for use on fires in combustibles could be reduced from five to one.

Now let us look at the five extinguishers sold for use on oil, grease, or gasoline fires. As we have just seen, the foam and "loaded stream" types have definite drawbacks.

The vaporizing liquid extinguisher using either carbon tetrachloride or chlorobromomethane as the extinguishing agent can be purchased from the mail order house, the corner drug store, or neighborhood hardware store. Few of the people selling or buying this type of extinguisher realize the high toxicity of fumes produced by the liquids used. Many health and medical authorities condemn this type of extinguisher. We would do well to eliminate it from the list.

This leaves the carbon dioxide and dry chemical extinguishers and a choice between these two is difficult. For many, the carbon dioxide extinguisher is attractive because it leaves no residue. On the other hand, trained fire fighters often prefer the dry chemical type for certain fires because of its lesser tendency to "flash back" with use.

Finally there are three common types of extinguishers recommended for electrical fires. All three can be used on oil fires, and have been considered already. Leaving out the vaporizing liquid extinguisher for reasons already stated we have left the carbon dioxide and dry chemical types.

We have then eliminated five of the eight common types of fire extinguishers for use in buildings and have left only three: (1) charged water extinguishers for fires in combustibles and (2) carbon dioxide, (3) and dry chemical types for oil and electrical fires.

Since the last two types are rather close in performance, it is quite possible that one of the two could be adopted as a standard. Exhaustive testing under a wide variety of conditions would be necessary to establish a preference.

A Plea for Uniformity

Actually, substantial differences in performance do not exist and selection of any one type for each of the three kinds of fires is based largely upon personal preference.

Now how about the operating mechanisms of these basic types—could they be standardized? The answer is an unqualified yes, and such standardization is not only possible but has already been done.

One manufacturer has on the market charged water, carbon dioxide, and dry chemical extinguishers that are practically identical in appearance and operation. The method for operating them is so simple that it is obvious even to the uninitiated.

There are many reasons that would explain the present situation. Tradition, customer demand, or competition, would impede a change in established practices. Nevertheless, from the viewpoint of public safety, much would be gained from the transition. Confusion in customer's minds would be eliminated and the stage set for much wider use of this important fire fighting device.

Here indeed is a challenge to industry. An opportunity to serve the public better and to expand markets at the same time. At the same time thought should be given to further improvements such as lighter weights, better design—even an all purpose extinguishing agent. These things will come in time—the opportunity for simplification is here today.

—by C. H. Yuill, Southwest Research Institute, San Antonio, Tex., in *Tomorrow*, June, 1955.

The Controller's Function

A controller, in my opinion, is the logical generalist to assist management in working toward its short- and long-range objectives, particularly in the profit sense. His experience with the constant flow of data throughout the accounting system and other factual systems which he directs should enable him to evaluate in financial terms the results which might be expected from any composite planning, even in such diverse areas of operations as marketing, production, maintenance, shipping, communications, inventory, warehousing, materials handling, etc.

Our company's Insulite insulation board division at International Falls, Minn., has four insulation board machines producing 24 hours a day, 7 days a week. This rate has been steady since 1949. Even this production level, representing 100% of available capacity, has fallen far short of satisfying customer demand. Naturally, this situation presents a good many interesting and difficult questions. Here are a few:

1. Should we, in this prolonged sellers' market, maintain a complete product line, or should we concentrate on the items which give us a maximum profit margin?
2. Should we expand our production of the present line, and if so should we expand at our present location or at some other location which would permit a lower cost of distribution?
3. Should we carry on with the present product line at its present volume and undertake expansion through the medium of some entirely different type of product which would lead to additional market flexibility and perhaps avoid some of the seasonal variations normally experienced in the construction business?
4. Should we continue to market our present line in its pres-

ent volume in 45 of the 48 states, and what would our long-term market risk be if we were to reduce our marketing area and try to maintain a larger share of the available market closer to the plant?

As a result of sales urging for more capacity, the Engineering and Production Division came up with one recommendation that four more drying decks in the kiln from no. 1 Insulite machine should be added. The capacity of the machine was then about 78 million feet annually. The suggested kiln expansion would provide an additional 30 million square feet. Naturally, there was a great deal of discussion about increment profit, customer satisfaction, etc.

The next degree of pressure originated with the Technical and Market Research Divisions arguing for product diversification into different density ranges. This was intended to offer higher margins, more market stability, and distribution closer to home, but the diversification would sharply reduce the volume of existing products.

The third pressure area involved no change in the type or volume of production. Instead, the Central Engineering and Industrial Engineering Divisions stressed greater efficiency in the plant, enabling more quality uniformity, fewer culls and lower costs, generally through improved mechanization and materials handling.

In our efforts to develop objectivity in analyzing the priority among these three divergent points of view, and to be sure that no one specialist division in the company should tend to dominate management thinking, the controller was first asked to develop a basic yardstick against which variations in the planning could be measured. This was quickly and easily drawn from the current plan of operation.

Next, management amazed the controller by requesting a study of the economics of a thee-machine Insulite mill with a directly prorated reduction of all charges, including manufacturing, maintenance, fixed charges, selling expense, freight, etc., with a reduction in new sales, of course, and a theoretical reduction in sales territory to match the reduced capacity. In other words, management wanted to know *not* what the profitability would be of an extra 30 million square feet from no. 1 machine, but exactly what the profitability was of the 78 million feet then being produced on this unit.

Having reduced this operation down to a three-machine level, management then reversed its field and gave the 78 million feet of production back to the Sales Department and the controller with the questions: How and where do you propose to merchandise this "new" production? What would be the over-all market risk if the 78 million feet were distributed in the smaller three-machine area?

In reply, the controller next developed theoretical situation no. 3. This involved the distribution of total production from the four existing machines into the reduced geographical area which had been replotted to support the production from three machines only. This demonstrated that earnings would be substantially increased over the current plan of operations, largely due to savings in freight and sales expense.

It was then decided that the controller should prepare a further case involving the restricted distribution area, but adding some 50 million square feet over the four-machine production to see what the profit potential might be, irrespective of risk. Obviously, this case rendered a splendid return on the capital investment required, but was not in the least practical.

To be more realistic, therefore, the controller next prepared case no. 5, which moved the increased volume back into our regular 45-state sales area. In case no. 6, the national distribution pattern was maintained, but weight was given to the possibility of altering the product mix. The controller's department next pulled together case no. 7, involving a substantial capital investment for an entirely new line of products to be produced to some extent at the expense of existing production volume. National distribution was again the pattern. The picture which began to emerge at this point in terms of product and market flexibility, unit profit, and profit in relation to required capital investment was most interesting and enlightening.

Eleven cases in all were prepared, giving effect to reduced volume in a small market area; increased volume to be distributed nationally; variations in product mix; a new line of products in addition to existing production and product mix, etc. All this effort was guided to a successful conclusion by our controller acting in his generalist capacity as an "operations researcher."

In the final analysis, the first priority went to product diversification; the second to greater plant efficiency and a cost reduction program, and the third to a moderate horizontal expansion. The final upshot is that our company is making capital investments totaling something over $2.25 million for this special area of its operations. Construction started a year ago, and profit realization should commence toward the end of 1955.

The kind of teamwork demonstrated here, leading to greater and surer profits, is the true fabric of industrial success in this country today. It is also a tribute to the stamina and knowledgeability of the controller fraternity as a whole.

—Excerpted from an address by Robert Faegre, executive vice-president, Minnesota and Ontario Paper Co.

Automation

Some of the most exciting pictures presented to the public concerning the future of American industry have been summed up in the relatively new term—automation. Contained in the overtones of formal definitions are visions of automatic factories and offices, economic abundance, and plentiful leisure. Regardless of how these prophecies originate, no one doubts that a new and "automatic" era is in the making.

Automation is the promise of a second or third or even final industrial revolution—a Robot Age of unmanned production. It represents the desire and the methodology for taking people out of all phases of the production process.

Mechanization—basic to the growth of industrial production for almost two centuries—was characterized by the desire to shift from manual to machine methods. By definition, it reduced the extent of human participation in any mechanized process. But the emphasis was put on reducing one kind rather than the total of human participation.

The addition, for example, of a small gasoline engine to the old-fashioned lawn mower was mechanization. The human operator used less energy and had the lawn cut sooner, but continued to guide the machine over the lawn and decide if an adequate job had been done at every step along the way.

In the new age, the automatic lawn mower merely would be instructed concerning the area to be cut and the kind of cut desired. The operator, of course, might have to warn the mower to avoid rocks, trees, the house, and the dog.

(It is left to science fiction to consider another age when one would merely say, "Lawn mower, keep the lawn manicured.")

Automation is more than a substitution of machines for manual sources of energy. Automation is predicated on replacing a broad range of sensory and judgment features formerly reserved for the human operator.

For example, machines are used not only to work on materials as in the past, but to convey material from one production stage to another and, ultimately, to dispose of the product at the line's end.

No longer under immediate human direction, the production and conveying machines are themselves controlled by still other machines. These are designed to note like human operators the current state of the production process and to take the necessary corrective actions for every deviation from a set of standard conditions.

This control of one set of machines by another set of machines is the key to automation. Through such control the various functions of materials handling, machine setup, continued inspection, machine adjustment, and even the collec-

tion and organization of operating and accounting data are integrated into one process.

The controlling machines are designed to measure the properties of both the process elements and the product at each stage and convert these measures into useful information for all levels of control.

They must possess impressive means for identifying, classifying, merging, calculating, and dispatching the now endless streams of data they receive. And they must be equipped for making comparisons, rendering routine decisions, and controlling the large amounts of energy necessary for continuous adjustment of the process.

The term automation is somewhat less than 10 years old. Its inventor is said to be D. S. Harder, a Ford Motor Co. vice-president, and its original use was intended for such factories as the Ford engine plant at Cleveland.

Along the 1600 ft. of one line at this plant, engine block castings are moved automatically from station to station for milling, grinding, drilling, tapping, boring, and honing operations. There is virtually no human intervention in the more than 500 separate operations and inspections performed. The engine block which formerly required hours on the line now is complete in a matter of minutes.

This factory certainly represents a solid accomplishment in automation. While the Ford plant is of unusual magnitude, similar plants have existed for many years and are seen widely in the automotive industry, among plate glass manufacturers, large canneries, sheet metal fabricators, some paper plants, and soft drink bottling works.

Such operations, however, are restricted generally to one product or a very narrow product class, and industries which employ them are somewhat unique in the American economy. They usually are characterized by extremely stable or large markets.

Sometimes their product is expended completely and the demand for the product consequently renews itself. More frequently the product is basic to the total economy and thereby is assured a stable market. In any case the product changes little over many years and requires few process changes. The volume of production in the interim is vast.

A large part of industry, however, does not find itself in circumstances so favorable to automation. Most firms are forced to rely upon a basic complement of equipment to produce many parts and products. And these must serve a set of constantly changing market conditions.

The elimination of people from processes produces a fundamental change in the nature of a business operation. A large part of the cost of a product is variable because it represents direct labor. Thus, production levels may be changed and new products introduced (or old ones dropped) by adjustment of the labor force.

As the costs of direct labor shrink in the automatic plant, more of the unit cost of the product derives from fixed sources. In order to be profitable, the plant then must operate at fairly constant levels.

If the market for a single product fluctuates widely (beyond the limits of reasonable inventory accumulation) then the plant must be capable of maintaining its rate by producing a variety of products and thereby construct a more uniform market. Clearly, a high degree of automation creates many nontechnological and as yet unexplored problems for a firm.

The alternative to the highly automatic, single product plant allows product shifts to meet demand. To accomplish this, complete and independent controls of separate operations and materials are required.

For example, a machine tool is designed for a specific set of operations upon specific materials in the single product plant. The more flexible plant must be equipped with machine tools capable of performing any one of a great number of basic operations on a variety of materials. For automation, however, the flow of work and tools into and out of each machine and among the various machines must be governed by a set of easily-changed instructions through another machine that replaces human operators.

Many of the engineering principles necessary to the design of equipment for a flexible plant in the above sense now are well developed. In particular, the theories of feedback and servomechanisms have been evolved carefully and these are essential to fully automatic factories.

However, there are few examples of complete plants. From an academic point of view, probably the only near examples exist in such industries as petroleum, chemical, paper, and munitions. The kind of thinking which is more or less readily applied to these continuous process plants is more difficult to apply to the flow of materials in the metal working, materials handling, and general assembly industries.

Representative results in metal working are such *separate* machines as the programmed engine lathe and the magnetic tape controlled lathe. In materials handling, punched card controlled conveyer chains and code-controlled pneumatic tube systems have been announced and installed in several plants. The use of printed circuit techniques, the "Tinkertoy" type module, and the United Shoe Machinery Co. assembly machines are taking root quickly in the electronics assembly industry.

It cannot be pretended, however, that these examples use more than a fragment of the available principles and components. Most remain promising engineering ideas and tools at the present time.

Prompted by a continuous need to reduce unit cost and meet increasing consumer resistance, American industry is spending billions on the development of more automatic processes.

A great deal of discussion has centered on the question of upgrading labor in the forthcoming period. It is self evident that more highly skilled workmen will be needed to service and monitor the exceedingly complex equipment which automation utilizes. More people will be trained to engineer, design, program and operate this equipment.

In both cases one can expect corresponding rises in salary levels and a consequently higher standard of living in much the same way as occurred in the history of mechanization.

Of more immediate consequence, the number of people performing routine clerical functions in the Nation's offices will decline.

Business machines are the basis for one of the most rapidly expanding industries in the country, and the very new field of electronic data processing is showing an even more astounding growth.

But as more routine decisions are left to machines, a greater burden is placed upon skilled management to understand each detail of the enterprise and to formalize effective and profitable decision making procedures. This management must be responsive to new pressures on the firm and be able to formulate new policies quickly. Many must become skilled in setting up detailed procedures based on policy. Understanding even the intricacies of programming large data processing systems is necessary to use them best.

More significant, possibly, will be the shift of personnel from the center of the organization to its periphery. Large staffs will be required to meet the public. More effort will be expended in the sales and service areas of the business in an effort to assure uniform markets and continued plant utilization.

The tremendous growth of the white collar class will be a continuing proposition in America.

The most serious problem by far will be the need to meet these changes as they occur. Major units of the population will undoubtedly require upgrading in very short periods of time. Various regions will realize changes at different times. Consequently, great shifts in the working population will take place in order to fulfill the needs for skilled labor and simultaneously avoid massive unemployment.

It can be expected that industry and government will have to assume new responsibilities during these adjustments, first,

to avoid unnecessary hardship and, second, to assist in the massive training and relocation programs required. Planning and cooperation will be imperative for the agencies of labor, industry, and government.

Automation relies, of course, on continuous and expanding research and development activities in order to become a reality. The development of new products, processes, systems, and mechanisms relies heavily on the engineer's training, skill, and ingenuity.

From his point of view most problems are merely local. That is, he must solve the singular problems of his department, plant, or product. But the area in which the problem arises is often secondary. The textile and food industries and the insurance office are equally fair game for his efforts.

It is satisfying and surprising to see how rapidly new areas are being tackled and subdued. The automatic factory and the automatic office will thrive because we demand higher production at lower cost, less human effort, and greater leisure and adaptability to the shifting demands of a better educated market.

—by David Rubinfein, in *The Frontier*, summer, 1955.

Wastepaper Fodder

U. S. patent no. 2,715,067 has been issued to Jonas Kamlet, 300 4th Ave., New York, N. Y., covering the use of waste newsprint as feed for cud chewing animals. The invention will use the lowest grades, rotted wastepaper being most suitable.

Converted Flexible Packaging Products

The Bureau of the Census, Washington 25, D. C., has published a leaflet giving data on the shipments of various types of converted flexible packaging products. The leaflet, *Facts for Industry* Series M 26 F 15, is available from the bureau at 10 cents per copy.

Container Estimating

"Pricing and Estimating Methods for the Boxboard Container Industry," is the title of a new book published by *Boxboard Containers*, 22 E. Huron St., Chicago, Ill., and available from the publishers at $5.00 per copy.

Lumber Industry

"Facts about the Nation's Lumber Industry," 1955 edition has been published by American Forest Products Industries, 1816 N St. N.W., Washington, D. C.

Forestry Publications

Station Paper No. 76, "Forest Insect Conditions in the Northeast—1954," has been published by the Northeastern Forest Experiment Station, Upper Darby, Pa.

Wood Handbook

An enlarged and completely revised edition of the U. S. Department of Agriculture's Wood Handbook, the bible of the woodworking and construction industries, has been issued by the U. S. Forest Products Laboratory, and is available from the Superintendent of Documents, Government Printing Office, Washington, D. C., at $2.00 per copy.

Chips from Timber Waste

About 200 chipper plants have been installed in the Douglas-fir region of the West Coast, for the reduction of wood waste to chips for pulp production. More than half the wood requirements of the West's kraft industry—about 1500 tons a day—comes from bark-free edgings, trim, slabs, plywood tails, and other sound wood unsuitable for lumber or plywood.

A large factor in this development was the production of a specially designed small chipper by Sumner Iron Works, Everett, Wash.

A new kraft mill at Albany, Ore., scheduled to go into production this month, will operate entirely on leftovers from nearby mills. Three other kraft mills are planned for Oregon and most of their wood requirements will be filled by salvage wood.

The recovery program has also been aided by the development of a new type of chipper blade by Oregon Steel Foundry Co., Portland, Ore. Some of the largest mills have installed hydraulic whole-log barkers to provide bark-free slabs, and several have Nicholson whole-log mechanical barkers, but the cost of this equipment is too high for any but the largest mills.

Mexican Sulphur

Inaccessibility, and lack of fuel and transportation have hampered the development of the sulphur industry in Mexico. However, three plants are now in operation and by next summer U. S. companies alone are expected to be producing at a rate of over a million tons annually. In addition, Mexican interests are also entering the field, and it is predicted that within 20 years Mexico will become the world's major producer.

Racquette River

The addition of automatically controlled Chemipulp circulating hot acid systems to two sulphite digesters at the Racquette River mill in Potsdam, N. Y., has resulted in an increase in yield of around 20% with about a 20% decrease in cooking time. At the same time, we produce a pulp of uniformly high quality in spite of the fact that we change from spruce to hemlock and back several times a week.

Quality has also been stepped up. Prior to the installation of the new system, we obtained the following average figures: initial burst 0.74; tear −1.20. With the new system, cooking spruce, these figures jumped to: initial burst 0.97; tear −1.50.

On cooking green hemlock, we are able to obtain an initial burst of 0.80 and a tear of 1.44. It may be of interest to note here that a few months ago, when handling a batch of green hemlock, the finished paper was shipped to the customer just *seven* days after the trees were felled.

Although the increased yield and improved quality are undoubtedly very worth-while benefits, we cannot help but feel that the major benefits derived from these new systems are uniformity from batch to batch, and the ability to control the quality of the pulp within very narrow limits.

These benefits are attributable to two things. In the first place, the continuous circulation of the hot acid through the digester makes for much better heat distribution throughout the charge, a factor which makes it possible to consider the temperature of the acid leaving the digester as being representative of that of the entire digester charge.

Secondly, this temperature is accurately measured and closely and automatically controlled over a carefully calculated time-temperature schedule.

Integral Cam Programmers

The two instruments responsible for automatically controlling conditions within the digester are integral cam programmers. That is, each one incorporates a plastic motor-driven cam that has been cut to conform to the desired time-pressure or time-temperature cycle. As each cam rotates, a follower, bearing upon its periphery, mechanically repositions the instrument's set point index. The control unit in the instrument then continuously repositions the steam or relief valve to produce the desired time-temperature or time-pressure relationship within the digester.

The time-temperature controller is an integral cam "ElectroniK" instrument actuated by a thermocouple inserted in the hot acid line downstream from the hydroheater which injects steam into the circulating acid. Controlled air from this instrument positions the hydroheater steam supply valve,

thus regulating the temperature of the acid, and consequently that of the digester charge.

A time-pressure controller of the integral cam type measures digester pressure and operates the relief valve.

With these two cam program controllers, it is possible to bring a digester to the desired conditions over an exact time schedule, a virtual impossibility with manual control.

An ElectroniK strip chart recorder mounted below the time-temperature controller on each of the two digester control panels continuously plots values of the following three temperatures: (1) acid leaving digester; (2) acid leaving hydroheater; (3) digester charge.

By consulting this chart record, the digester cook can rapidly check conditions within the digester and compare them with acid temperatures in other parts of the circulating system.

Other Instruments Also Help

In addition to the basic instrumentation just described, several other instruments contribute to the highly successful operation of our pulp mill. Recorders, also panel mounted, chart digester level and the loads on circulating pump-drive motors.

In the acid plant, the application of a Brown controller to the liquid level of the sulphur in our sulphur burner has a great deal to do with our ability to produce between 18 and 18.4% SO_2. This level is measured by bubbling air through the molten sulphur in the burner and measuring the air pressure required to force the bubbles from the dip tube. The instrument automatically controls level by regulating the amount of molten suphur fed to the burner.

Brown instruments are also used on the accumulator where the digester relief gases are bubbled through the cooking acid, strengthening it and heating it in preparation for use in the next digester charge. Accumulator pressure is automatically controlled, while the temperature and level are both recorded.

Racquette River manufactures specialty papers in addition to selling lap pulp. Throughout all of our operations, the accent is on quality. In addition to the instrumentation, which makes it possible for us to consistently produce top quality sulphite pulp, we employ other equipment to see that this quality is maintained as the pulp passes through the various processing stages. Among this equipment are a Jonsson knotter, Bird consistency regulator, Cowan screen, and Bauer cleaners. All of these add up to one thing; a product that is recognized throughout the industry for its uniformly consistent quality.

—by B. Barrows and O. Wood, Racquette River Paper Co., Potsdam, N. Y. Reprinted from *Instrumentation* 8, No. 1 (1955).

Mead

Listed below are some of the major developments undertaken by Mead Corp. since the end of World War II. The company has spent $63 million in expansion and modernization in the past 10 years.

Kingsport, Tenn.:
- New storage warehouse
- Rebuilding and improving no. 3 and other paper machines
- New supercalender
- New and improved rewinders
- New finishing room
- New cafeteria
- Pulp refining equipment
- More color mixing equipment
- New and enlarged soda pulp mill
- Improved dry pulp machine
- Better power production facilities, including boiler and turbine

Macon, Ga.:
- New kraft linerboard mill (with Inland Container)

Rome, Ga.:
- New kraft linerboard mill (with Inland Container)

Brunswick, Ga.:
- Increased kraft pulp capacity

Chillicothe, Ohio:
- New soda pulp mill
- Mechanized woodyard
- Rebuilding and improving no. 7 and other paper machines
- New power production facilities, including boilers, turbine, and improved water supply
- New coaters
- New finished paper warehouse

Escanaba, Mich.:
- Rebuilding no. 1 paper machine
- New color building and equipment
- New groundwood bleach plant
- New warehouse

Wheelwright, Mass.
- New addition to finishing room

Sylva, N. C.:
- Two steam boilers
- Renovating two board machines, including a fourdrinier for no. 1
- Black liquor recovery pilot plant
- New hydrapulper
- Extension of warehouse
- Mechanizing woodyard

Harriman, Tenn.:
- New fourdriner for board machine
- Dual press for board machine
- Dorr sedimentation system
- Mechanizing woodyard

Lynchburg, Va.:
- New digesters
- Mechanizing woodyard
- Hydrapulper
- Rebuilding no. 2 board machine
- New laminated board building
- New polyethylene laminator

Nashville, Tenn.:
- New gas-fired boiler plant
- New vat for board machine

Research Laboratories:
- New labs and pilot plant building

Oxford

Oxford Paper Co., Rumford, Me., has recently introduced three new coated offset papers. As the result of an exclusive coating formula, these new papers—Planoflex, Swift River, and Uniflex—feature a bright level, polished surface which promises outstanding press results in either black and white or full color reproduction.

Scott

Scott Paper Co., Chester, Pa., has announced plans for a multimillion dollar installation of additional pulp and paper making and converting equipment in the company's Mobile, Ala., plant. The installation will be used to produce the first Scott household products ever manufactured in the South.

The present Scott plant at Mobile is one of the most modern pulp and paper mills in the world. It was acquired by Scott last October in a merger with Hollingsworth & Whitney Co., whose brands of paper products will continue to be manufactured at the plant. James L. Madden, who was president of Hollingsworth & Whitney, became a Scott vice-president at the time of the merger.

The pulp equipment will include additional digester capacity, new recovery boiler equipment, and wood preparation and water treatment facilities. Together with the rearrangement of existing bleaching facilities, the equipment will make possible the production of a minimum of 120 additional tons of bleached pulp per day.

Paper facilities will include new high speed papermaking machinery and roll tissue and towel converting equipment. Buildings will be constructed to house the papermaking machinery and converting equipment, and a shipping warehouse will also be erected.

Number 11 paper machine at Scott's Detroit, Mich., mill is nearing completion.

Scheduled to go on the line this month, the new unit will produce ScotTissue and Waldorf, thereby rounding out the production of all three brands of Scott toilet tissues at that mill. Current production at Detroit is devoted to Soft-

Weve and Scot-Tissue, both of which are being made, finished, and shipped from the mill.

The current construction is part of a $6 million expansion program planned for the Detroit site. It is possible that the company will spend a total of $20 million at this mill over the next 5 years.

In conjunction with the construction of the new machine, the expansion program underway includes the construction of a series of connected buildings adjoining the present paper mill, the largest of which will house the new paper machine. This building will also provide room for an additional paper machine which is already in the planning stage for Detroit. Other units will provide additional pulp storage, paper finishing and shipping areas, laboratories, and office space.

Brown Co.

The Brown Co., Berlin, N. H., has started construction of a new kraft bleach plant expected to cost $3.5 million.

President Dwight D. Eisenhower was a visitor to the Brown Co.'s Parmachenee Club in the Upper Androscoggin.

Riegel Carolina

Riegel Carolina Corp., Acme, N. C., has organized a maintenance control center for the planning and recording of preventive maintenance on mill equipment.

Union Bag

John A. Christian, Jr., has been appointed manager of the Chicago box plant of Union Bag & Paper Corp., Savannah, Ga.

Nepco

The Nekoosa Foundation, charitable and civic outlet for Nekoosa-Edwards Paper Co., Port Edwards, Wis., has established a $25,000 fund to aid in the support of medical or surgical research at the University of Wisconsin.

Crown Zellerbach

A new chemical by-product of the pulp and papermaking process will be marketed next year by Crown Zellerbach Corp. Camas, Wash. To be given the trade name Greenz 26, its use will be as an agricultural mineral to correct iron deficiency in plants. This deficiency is known technically as iron chlorosis and is typified by a yellowing of the leaves of trees and plants.

The inventor, J. P. Bennett, formerly with the University of California at Berkeley, is a recognized authority on iron chlorosis. Much of his life's work has been in diagnosing and treating such "illnesses" in plants. He has been working on the development of this new product for the past 2 years in collaboration with C. Emlen Scott, extension plant pathologist, and has thoroughly field-tested it on pears in the area near San Jose, Calif. This year a large number of test plots have been established on pears, as well as peaches, prunes, and other crops in the western half of the United States.

W. Ronald Richardson joined Crown Zellerbach on September 1 as assistant to the director of public relations in San Francisco, Calif.

New York & Penn

As part of its 65th anniversary celebration, the New York & Pennsylvania Co. is preparing an anniversary brochure describing its history and growth in the papermaking industry.

NYP was founded in 1890, when Col. Augustus G. Paine formed a merger between the Pennsylvania Pulp and Paper Co., with mills in Lock Haven and Johnsonburg, Pa., and the Champlain Fibre Co. at Willsboro, N. Y. In 10 years' time the new company had almost tripled its annual output. In 1920, a new streamlined plant, the Castanea mill, was built alongside the original mill at Lock Haven.

Today the company can produce 85% of its own pulp

New York & Pennsylvania Co. plant at Lock Haven, Pa.

requirements and 500 million pounds of paper a year—25 times what it produced that first year in 1890. Sixty-five years after it was formed, the company has 10 times as many employees. each of whom receives in take-home pay and employee benefits more than 10 times what the average employee did in 1890.

In its 65th year, NYP is supplying paper for more than 27 million magazines a month. New York & Penn papers are used today by offset and letter-press printers, book and magazine publishers, greeting card manufacturers, consumers of mimeograph and duplicating paper, and school supply houses all over the country.

Riegel

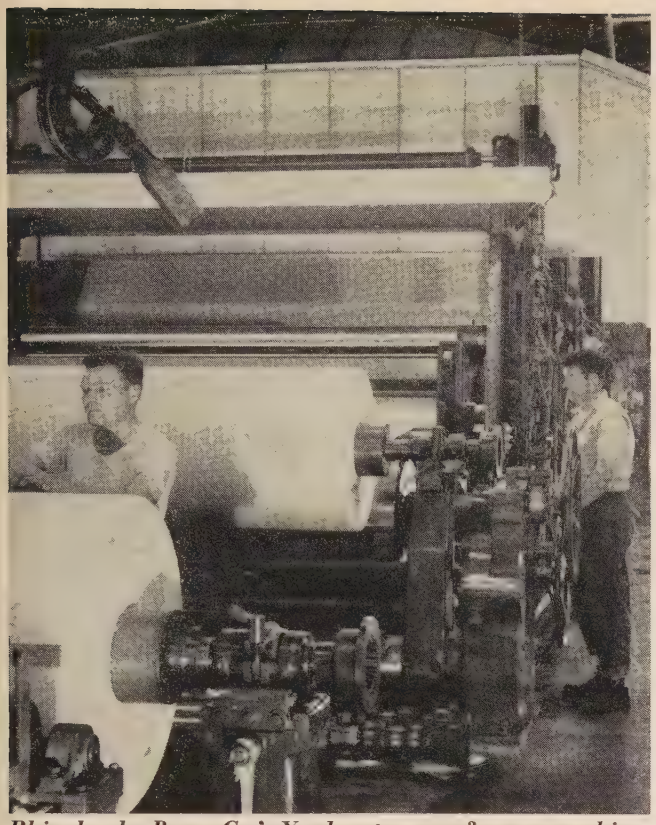
Riegel Paper Corp. faces an unusual problem due to the development of an amazing new paper that is extremely resistant to passage of oil, water, and other liquids, but will permit air to pass through freely. Having developed it, the question is "what to do with it?" Some folks say it's just right for paper raincoats that will shed water but keep the wearer cool on hot days. . . others think it's perfect for popcorn bags that won't leak grease and can't be blown up and popped in theaters. There must be many other uses for this amazing new paper but Riegel wants to know "Who can use it. . .who needs a paper with these extraordinary properties?" They're willing to talk to anyone with ideas on the subject. Further information is available from Riegel Paper Corp., 260 Madison Ave., New York 16, N. Y.

Rhinelander

No. 3 Machine Modernization. Rhinelander Paper Co. has completed the rebuilding of its no. 3 paper machine after a shutdown of 74 days.

The project required an investment of more than $1,000,000, and is another major step in Rhinelander's plant improvement and expansion program in which capital expenditures of $16,000,000 have been made since World War II.

No. 3 is a Yankee-type paper machine, now designed to produce a sheet approximately 123 inches wide at high speeds. The machine was rebuilt from end to end with the introduction of many additions and improvements including larger and better stock preparation equipment, a pressure-type inlet for distributing pulp stock to the wire, an entirely new pre-drier section, a new Yankee drier, an automatic reel, a new steam turbine drive, antifriction bearings, improved lubrication facilities, and other important features. All piping carrying the stock is made of stainless steel to insure maximum cleanliness in the finished sheet.



Rhinelander Paper Co.'s Yankee-type no. 3 paper machine, newly modernized and enlarged at a cost of more than $1,000,000, to manufacture sulphite specialty papers mainly for food packaging. The machine produces a sheet 123 in. wide at high speed

This is one of eight paper machines in the company's mill at Rhinelander, Wis. Seven of the machines produce glassine and greaseproof papers, and two of the seven are believed to be among the largest machines in the world manufacturing these grades. No. 3 machine, however, manufactures

Yankee drier on Rhinelander Paper Co.'s completely rebuilt no. 3 paper machine

sulphite specialty papers (both machine-finish and supercalendered) which are used principally in the packaging of foods. These grades include stock for transparent bread wraps, high density waxing and foil-mounting papers, waxing tissues, wet-strength papers for packaging butter, meat, and other perishable foods, pouch papers for heatseal uses in packaging.

The modernization project now enables the machine to turn out a wider variety of such papers, in considerably larger volume, and with improved quality, particularly in the formation and density of the sheet, properties which facilitate the processing in converters' plants. Operating efficiency has been improved.

Spent Liquor Utilization. The Rhinelander mill has had installed since late 1948, Wisconsin's first torula yeast plant for processing sugar out of spent sulphite liquor, and since late in 1951 has been operating this state's first sulphite evaporator plant. All collected liquor from this mill is first desugared in the yeast plant. Then it is evaporated and the concentrate is either sold as a raw material to chemical processors or burned as industrial fuel.

St. Regis

St. Regis Paper Co. has acquired more than 95% of the outstanding capital stock of General Container Corp. of Cleveland, Ohio, as a result of an offer of exchange made by St. Regis and which was declared effective as of Aug. 25, 1955. Under the terms of the offer, the holders of General's capital stock will receive $2^3/_8$ shares of St. Regis common for each share of General.

General Container, whose principal offices are in Cleveland, had sales in 1954 in excess of $23,000,000. At the end of 1954, General had 134,656 shares of common stock outstanding with no preferred stock or bonds.

General is engaged in the manufacture of corrugated fiber shipping containers and allied products, folding cartons and set-up boxes, and corrugating medium and container chipboard. Its customers include manufacturers of automotive parts, household appliances, food products, metal products, textiles, paper converters, and the jobbing and retail trades.

The products manufactured by General are produced at plants at the following locations:

Corrugated fiber containers, and allied products:
- Albany Corrugated Container Corp., Cohoes, N. Y.
- Canton Corrugated Box Co., Canton, Ohio
- Cleveland Corrugated Box Company, Cleveland, Ohio
- Dubuque Container Co., Dubuque, Iowa
- Hunt-Crawford Co., Coshocton, Ohio
- Niagara Corrugated Container Co., Inc., Buffalo, N. Y.

Folding cartons and setup boxes:
- Great Lakes Box Co., Cleveland, Ohio
- Crowell Carton Co., Marshall, Mich. (folding cartons only)
- Dubuque Container Co., Dubuque, Iowa

Corrugating Medium and Container Chipboard:
- Muskingum Fiber Products Co., Coshocton, Ohio

Approximately 1400 persons are employed in General's nine plants. The entire General organization will remain unchanged and management continued as in the past with Dan L. Pickering, chairman of the board, and Robert W. Agler, president.

The acquisition of General is a further step in St. Regis's broadening of its operations in the paper converting and container fields. St. Regis manufactures printing, publication, and converting papers; bleached and unbleached kraft pulp, paper and board; multiwall paper bags and bag making bag filling equipment; fiberboard containers and a broad range of industrial and decorative plastic products.

St. Regis has started work on the expansion program at its Jacksonville, Fla., mill. This includes the installation of a new 1000-ton-a-day kraft paperboard machine as well as expansion of the pulp production facilities there. Target date for the completion of the expansion program is May, 1957.

Engineers for the pulp mill and its buildings and equipment are J. E. Sirrine Co., Greenville, S. C. Stevens & Rubens of Seattle, Wash., will engineer the board machine and its buildings and equipment. Construction will be handled by Tidewater Auchter Construction Co.

The new machine, which will be built by Beloit Iron Works, Beloit, Wis., will have a maximum speed of 2500 f.p.m. Over-all length of the machine will be 650 ft. with a four-drinier wire 276 in. wide which will produce a trimmed sheet 255 in. wide. It is being designed to produce paperboards ranging in weight from 38 to 69 lb. per 1000 sq. ft.

Four or five additional wells each 1200 feet in depth will be drilled in order to provide the 25,000,000 gal. of additional water required daily for the expanded facilities. This will make a total daily consumption of water at the mill of 35,000,000 gal.

To meet the power requirements for this expansion, a 30,000-kva. turbogenerator will be installed as well as two oil-fired steam boilers with a capacity of 200,000 lb. per hour, one bark burner of 135,000 lb. per hour capacity, and two recovery boilers each with a capacity of 140,000 lb. per hour. All steam will be generated at 625 p.s.i.

In addition, two new lime kilns 9 ft. in diameter and 250 ft. long, will be installed as well as two new precipitators; two barking drums, 12 ft. in diameter and 67½ ft. long; and two large chippers approximately 100 in. in diameter.

It will require an additional 80 carloads of pulpwood daily to supply the wood requirements of the new machine. This will bring total consumption of wood at the mill to approximately 100 carloads daily.

Justin H. McCarthy, vice-president of St. Regis and chief engineer, pulp and paper, is in charge of the expansion program and Lawrence C. Crowder is project engineer.

Marathon

Marathon Corp., Menasha, Wis., has purchased the Meridian & Bigbee Railroad Co., which operates a line between Meridian, Miss., and Myrtlewood, Ala. The company has also purchased a paper mill site about 110 miles west of Montgomery, Ala., and is considering plans for an integrated pulp, paper, and paperboard mill.

I. P.

C. S. Sturgis has been named district manager of International Paper Co.'s Single Service Division. G. A. Husnik is now resident manager of the Division's Minneapolis plant, H. D. Gerring is resident manager at Kalamazoo, and F. J. Land is resident manager at Kansas City. Other new appointments are: W. S. Riedinger, Philadelphia, Pa., resident manager, W. T. Fyfe, Youngstown, Ohio, resident manager, M. L. Quinlan, Waco, Texas, resident manager, A. C. Barham, Bastrop, La., resident manager, and K. Gardner, Atlanta, Ga., resident manager.

The new five-color press installed at the plant of Arkell & Smiths, Canajoharie, N. Y.

Shawano

Shawano Paper Mills, Shawano, Wis., have completed arrangements for outright ownership of the paper mill property.

Arkell & Smiths

Arkell & Smiths, Canajoharie, N. Y., has installed a new five-color press for printing with heat set inks up to 500 f.p.m.

Northwest Paper

The following changes in The Northwest Paper Co. Manufacturing Department have been made: Roy I. Nilsen will become assistant manager of manufacturing, and will be located at the general office in Cloquet, Minn. Warren C. Johnson will succeed Mr. Nilsen as manager of paper manufacturing at Cloquet. Richard Maron will succeed Mr. Johnson as superintendent of the machine room at Cloquet. Sidney E. Strothman will occupy a newly created position of supervisor of beater rooms (both Cloquet and Brainerd, Minn.) under jurisdiction of the respective managers of paper manufacturing.

MacMillan & Bloedel

Expansion of Alberni Pulp Division of MacMillan & Bloedel Ltd., announced last January, has now moved from the planning stage into actual construction.

The additions to the present pulp mill will be: (1) a newsprint mill having daily capacity of 300 tons, with provision being made for a second unit; (2) increased capacity of 100 tons a day of unbleached sulphate pulp, to a total of 350 tons a day; (3) a multipurpose coarse paper and board machine with a daily capacity of 100 tons. Total cost will be about $35,000,000. Project engineers are H. A. Simons Ltd. of Vancouver, who designed and engineered the present mill, as well as the company's Harmac mill.

Rayonier

Rayonier Inc. will establish a new research center on an 82-acre site at Whippany, N. J., as a further expansion of its scope of research.

The chemical cellulose firm now has its research facilities concentrated at Shelton, Wash., where 150 scientists and technicians are employed in its Olympic Research Division. The New Jersey expansion will be known as Rayonier's Eastern Research Division. These facilities will further broaden the company's basic cellulose studies, with the Olympic Research Division continuing in full force.

Enka

A new high tenacity rayon sewing thread, which offers up to 30% savings on thread costs in the manufacture and closure of multiwall paper bags, is being produced by American Enka Corp. The superior strength and elastic properties of Enka's new product permit the use of a smaller size thread, which means greater yardage per pound. This feature, plus the initial price advantage over natural fibers, explains how savings of approximately 30% can be achieved.

In addition to the economic feature of the new thread, the relative stability of Enka's high tenacity rayon prices, as opposed to natural fiber prices, permits users to forecast their costs more accurately than was previously possible.

After 3 years of intensive experimentation and development work, St. Regis Paper Co., the largest manufacturer of multiwall paper bags in the country, has given complete approval to Enka sewing thread.

KVP

KVP can point with pride to the fact that it was one of the first industries in the Kalamazoo area to do something about stream improvement. Twenty-five years ago it dug the first settling pond for its waste water. Since then, it has added several more settling ponds, purchased huge, expensive machines that filter out waste inside the mill, and set up a continuing laboratory control program in an effort to purify its water before it is returned to the river.

How well has the program worked? A recent regulation of the Michigan Water Resources Commission allows KVP to discharge into the stream 10 lb. of solid waste material for every ton of paper production. In recent months, KVP has been able to reduce its waste discharge to well below that figure.

Despite such definite results, the company does not feel it has found all the answers to stream pollution as yet. Stream improvement is largely a process of trial and error conducted over a period of years. It involves extensive studies, a search for solutions, the purchase and installation of complicated and expensive machinery. Often another machine must be added when the first proves inadequate. Above, all, stream improvement depends upon close cooperation between mill departments and employees in seeing that not a single particle of unnecessary waste finds its way to the river.

During the July 4 shutdown week, Parchment maintenance men were busy on a special project—connecting long lines of pipe between the paper machines in mill 2 and a new tank-shaped, paddle-wheeled machine. Its tongue-twisting name: "Sveen-Pedersen saveall."

Latest addition to the expensive battery of machines installed by the company to combat stream pollution, the saveall does just what its name implies—it saves wood fibers and other paper ingredients from being lost to the river in the papermaking process.

Other savealls of varying types at Parchment accomplish the same thing. Mill 1 has a Waco filter and an Improved washer; mill 2 has a pair of Improved washers, besides the new Sveen-Pedersen.

Most of these machines are huge, complex pieces of equipment that were developed only after years of experimentation by the paper industry. All together, they cost the company hundreds of thousands of dollars. But by recovering fiber or chemicals which can later be reused in the papermaking process, they enable the company to salvage thousands of dollars worth of raw materials that were heretofore lost.

Most of the waste in KVP's "white water" is filtered out by the machines described before it leaves the mill. But some waste water, particularly that containing unrecoverable lime, chemicals, and dyes, is treated differently: it must be channeled into a bank of settling basins located north of mill 2.

As the water flows through these basins, the waste solids in the water gradually settle to the bottom. Then the clear water on top is allowed to flow into the river, and the settled waste is later scooped out and hauled away to a dump.

To make doubly sure that the water finally discharged into the river is as pure as the stream improvement program can make it, a rigid system of laboratory checks has been established. Three times daily, a chemist from Parchment's research lab takes samples of the water as it enters the river, later analyzes them to determine the percentage of waste. The results are then posted on special bulletin boards adjacent to the paper machines for everyone to see.

Air, like water is often used as a carrier of waste. Smoke from home incinerators, public dumps, burning trash, or factories constantly fills the air around us.

Compared with the oil, steel, or chemical industries, the paper industry is relatively smoke-free. In KVP power houses, the principal areas where smoke could become a problem, special equipment prevents excessive smoke from being created when coal is burned to generate power.

Pulverizers, or giant crushers, help the power house crew maintain efficient operation of the furnaces. The pulverizers grind the coal into small pieces, enabling the firemen to burn coal with a cleaner flame.

The new boiler being installed in the Parchment power house will also be equipped with a dust collector which is the most efficient mechanical smoke cleaner available. Large fans will suck the smoke, containing gases and solid particles of ash, from the boiler, then blow it through the dust collector where practically all of the ash will be filtered out. The ash will then travel into a giant silo, acting like a giant vacuum cleaner, after which it will be mixed with water and hauled away to the dump. The dust collector will prevent some 375 tons of ash from being discharged into the air each month.

Falls Paper & Power

On the banks of the Oconto River the Falls Paper & Power Co., Oconto Falls, Wis., has built a lagoon to hold more than 18 million gallons. This is as much collectible full-strength sulphite liquor as the company's pulp mill produces in 6 months of full-scale operation.

Walls of the big earthen bowl are built up as much as 20 ft. above the natural level, matching a ridge that forms one side. Surrounding dikes and the bottom are lined with a thick layer of compacted clay to make all watertight. A hill nearby is being cut down to yield the 75,000 cu. yd. of soil, gravel, and clay needed for constructing the lagoon. A creek that formerly ran through the site has been diverted to a new channel outside the dikes, and springs found in the old creek bed now flow into the river through pipes buried beneath the clay.

The lagoon is designed to receive by pipeline, to store, and thus to withhold from the river all full-strength liquor produced during hot, dry weather beyond what can be hauled away for roadbinder and other uses. As cooler autumn weather brings rain, the river increases its capacity to maintain dissolved oxygen while absorbing more spent liquor.

New Wood Waste Product

Development of a new and potentially significant raw material from wood leftovers was revealed recently at the ninth annual meeting of Forest Products Research Society in Seattle.

Francis H. Snyder, Brookfield, Conn., consultant, said the new product, known as Dendrol, has already been tested on a commercial scale. A solid, dark brown lignin derivative, Dendrol has some properties of thermosetting phenolic resins, thus suggesting a variety of industrial uses including a phenolic resin for molding materials, laminating varnishes, hardwood binders, and phenolic resin papers, Mr. Snyder said.

Citing over 35 million tons of residue already annually existant in woodworking plants alone, Mr. Snyder predicted the eventual creation of a "vast organic chemical industry based on wood substance as the raw material."

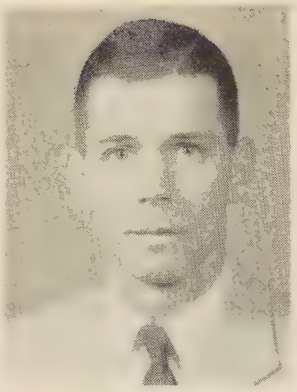
Every known organic chemical, he said, can be made from wood. The crux of the situation is economic, he added.

Oregon State College

Students of Oregon State College who intend to enter the pulp and paper industry or allied fields may elect to take in their senior year, technical courses in wood chemistry, wood analysis, pulp and paper chemistry, and pulp and paper testing. The processes of pulp and paper manufacture and the operation of the industry combine the fundamentals of the sciences, engineering, and wood technology. Undergraduate training for the pulp and paper industry can be approached either through the Department of Chemistry, School of Science, or through one of the professional schools on the campus, such as the School of Engineering, Depart-

ment of Chemical Engineering, or the School of Forestry, Department of Forest Products.

Oregon State offers graduate work leading to advanced degrees in several chemical fields. Prerequisite to graduate work leading to an advanced degree with a major in forest products chemistry is the completion of undergraduate work in chemistry, mathematics, physics, and biology, substantially equivalent to that required for graduation in chemistry from an accredited institution. Degrees offered are M.S., M.A., and Ph.D. in forest products chemistry.



G. D. Anderson, Western Michigan College

The Oregon Forest Products Laboratory on the campus of Oregon State College occupies approximately 19,430 sq. ft. of floor space. The wood chemistry laboratories are equipped to conduct research in the chemistry of wood, barks, and by-products. The pulping laboratory has most of the equipment necessary for the pulping and processing of pulp by the usual chemical and semichemical processes, including a laboratory wood chipper, chip screens, digesters, liquor preheater, a commercial-size Bauer pulper, a 12-in. Sprout-Waldron defiberizer, and pulp and paper testing equipment. Equipment and facilities made available by Oregon State College, or by other cooperating agencies, further extend research opportunities.

This laboratory carries out a broad program of research and development work in wood, bark, and by-product chemistry and utilization; on methods and processes of mechanical, semichemical, and chemical pulping; on the influence of various chemical additives to pulp, paper, and fiberboards to modify their properties; on the seasoning and preservation of wood; and timber mechanics.

Western Michigan

The Allied Paper Salesmen's Association has announced a 1955 scholastic award of $300 to Gene D. Anderson, a senior student this fall, who is also employed by the KVP Co. full time as a laboratory technician. Despite this rigid schedule he has maintained almost a B average in his college work.

Plant Maintenance & Engineering Show

The Plant Maintenance and Engineering Show will be held in Philadelphia, Pa., Jan. 23 to 26, 1956.

Chemical Exposition

The 25th Exposition of Chemical Industries will be held in Philadelphia, Pa., Dec. 5 to 9, 1955.

Graphic Arts Competitions

The following are some of the national competitions in the graphic arts field:

AIGA Design and Printing for Commerce

Probably the "toughest" competition of them all. Judging is based on effectiveness of all factors of the graphic arts: design, illustration, typography, engraving, platemaking, paper, printing, and binding. Closing date for entries usually December 31. Sponsored by the American Institute of Graphic Arts, 13 E. 67th St., New York 21, N. Y.

DMAA "Best Direct Mail Advertising"

Sponsored by the Direct Mail Advertising Association, 381 Fourth Ave., New York 16, N. Y. This year will be conducted on basis of the six functions of direct mail. Winners selected on results, copy, design, and continuity. Closes July 31.

J. W. Allis, Louis Allis Co.

E. P. Allis, Louis Allis Co.

ICIE Awards Program

Awards for company publications, both internal and external. Evaluation based on: editorial and content balance; writing quality; appearance. Usually closes in February. Sponsored by the International Council of Industrial Editors, with a different local member in charge each year.

LNA Lithographic Awards Competition and Exhibit

All types of promotional material which is produced by offset lithography. Judging in 16 classifications is based on: quality of reproduction; excellence of design; effectiveness of accomplishing objectives. Closes about March 1. Sponsored by the Lithographers National Association, 420 Lexington Ave., New York 17, N. Y.

Financial World Magazine's Annual Report Competition

Selection of the best annual statements in 100 industries from more than 5000 reports. Merit award winners listed first in *Financial World*'s last issue each June. Best of industry Oscar winners selected from the merit award winners and published in the last issue of each October. Deadline is about mid-June for sending copies to Weston Smith, *Financial World*, 86 Trinity Place, New York 6, N. Y.

Water Symposium

Louisiana State University, Baton Rouge, La., has published Engineering Experiment Station Bulletin No. 51, Proceedings of the Fourth Annual Water Symposium, held March 22–23, 1955.

Combustion Engineering

The following appointments have been made by Combustion Engineering, Inc., New York, N. Y.: Carmine J. Grossi, manager of Export Division; Frank J. Bader, assistant general sales manager in New York; and Herman C. Reichard, district manager in San Francisco.

Louis Allis

E. P. Allis has been appointed chairman of the board of the Louis Allis Co. John W. Allis is now president of the company.

Allis-Chalmers

Allis-Chalmers Manufacturing Co., Buda Division, Harvey, Ill., is offering a new FT Series fork lift truck, designated FPT30-24, with a capacity of 3000 lb. at 24-in. load center.

Hugh L. Ross and Charles L. Babb have been appointed assistant manager and chief engineer, respectively, of A-C's centrifugal pump department.

The new Allis-Chalmers fork lift truck

A-C has published a new bulletin (51B8166), available from the company at 828 S. 70th St., Milwaukee, Wis., describing the company's new package drives.

B & O

The Baltimore & Ohio Railroad has placed orders for 1500 70-ton hopper cars, 600 40-ft. 6-in. all-steel box cars, and 400 50-ft. 6-in. all-steel box cars. The total cost of the 2500 new freight cars will be about $18,500,000.

Minnesota Mining

Minnesota Mining and Manufacturing Co., St. Paul, Minn., is offering a new grease and oil repellent paper sizing agent, Scotchgard, which is said to coat the fibers with an oil resistant film, without affecting the strength, porosity, flexibility, appearance, or color of the paper.

C. N. S. Instruments

C. N. S. Instruments Ltd., 62 Rochester Place, London N.W. 1, England, are offering the C. N. S. Extensometer for the measurement of dimensional changes in hygroscopic materials.

Cleaver-Brooks

Cleaver-Brooks Co., 326 E. Keefe Ave., Milwaukee, Wis., is manufacturing a new line of industrial gas burners, at prices 30 to 40% lower than previous models.

Monsanto

Monsanto Chemical Co., Dept. S, Springfield, Mass., has published three technical service bulletins describing three new resins for the paper industry, designated Scriptite 50, 52, and 54.

Hooker

Hooker Electrochemical Co. has authorized a total of almost $3,000,000 to be spent at its Montague, Mich., plant for enlargement and product diversification.

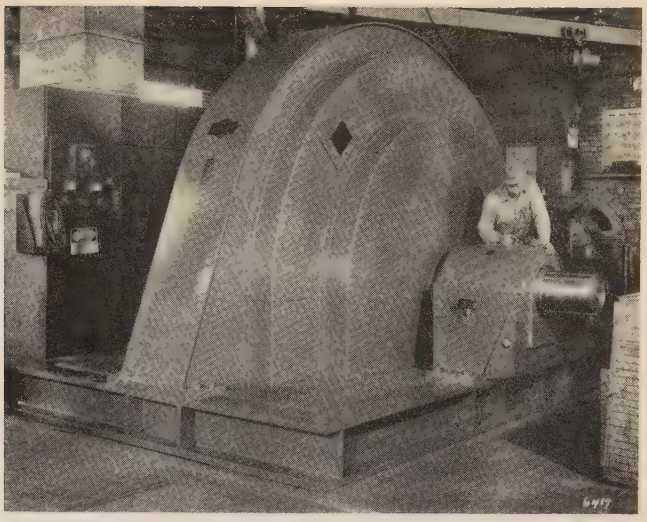
Foxboro

R. E. Rogers has been appointed manager of West Coast sales activities for the Foxboro Co., Foxboro, Mass. E. W. Pitt replaces Mr. Rogers as manager of Foxboro Los Angeles branch, M. F. Parr is regional engineer at San Leandro, and C. J. DeVilbiss is industrial engineer at Shreveport.

Foxoboro has issued a new bulletin (20-14), describing the magnetic flow meter for use on pulp stock.

Electric Machinery

Six 6000-hp. synchronous motors are being built for



Electric Machinery Mfg. Co. motor installed at Bowaters Southern

Bowaters Southern Paper Corp., Calhoun, Tenn., by Electric Machinery Mfg. Co., Minneapolis, Minn. The motors, which are 240-r.p.m., 4000-volt units, will be the largest ever applied to single pulp grinders.

Nalco

National Aluminate Corp., Chicago, Ill., has developed a new low-cost liquid antifoam, Nalco 71-B, designed specifically for the paper industry. Another new antifoam, Nalco 71-C, has been developed principally for paper machine operation on the acid side.

Another new Nalco development, designated Nalco 236, is a liquid slimicide and dispersing agent, containing no phenols or heavy metals.

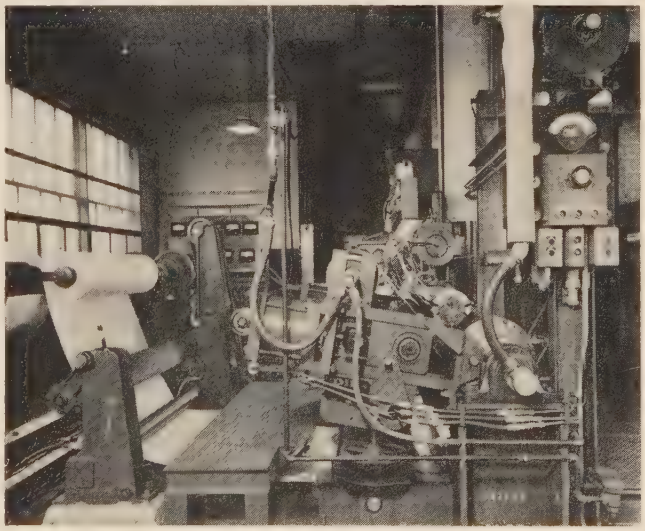
Cyanamid

American Cyanamid Co., New York, N. Y., has published a bulletin (No. 34), giving information on the chemical and physical properties and application of Polyacrylamide.

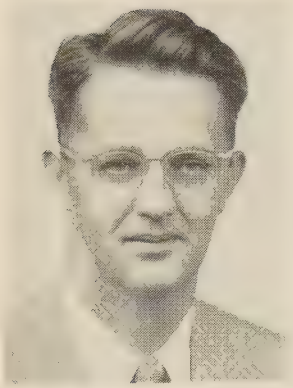
Verner Alexanderson has been appointed development manager for chemical intermediates in the technical department of Cyanamid's organic chemical division.

Black-Clawson

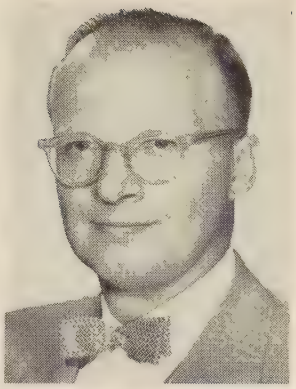
The Dilts Machine Works Division of Black-Clawson Co. has furnished a polyethylene extrusion laminator for locker



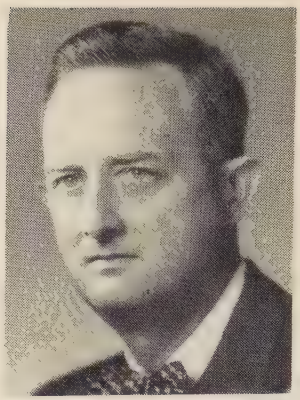
Dilts polyethylene laminator installed at Rapinwax Paper Co.



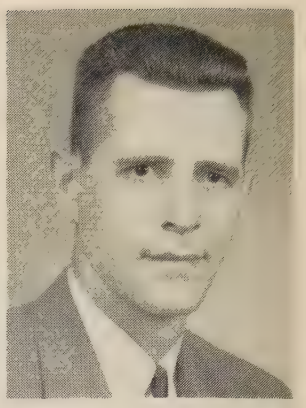
Jack McKela, Black-Clawson Co.



E. G. Kominek, Infilco, Inc.



T. O. Day, Milprint, Inc.



C. C. Spencer, Reichhold Chemicals, Inc.

wrap, foil, and cellophane, to the Rapinwax Paper Co., Minneapolis, Minn.

Jack McKela has rejoined the sales staff of B-C's Shartle Bros. Machine Division.

INFILCO

Edward G. Kominek has been appointed sales manager of Infilco Inc., Los Angeles, Cal.

FLECK

The Alexander Fleck Ltd., Ottawa, Ont., has acquired common stock holdings in Beach Foundry Ltd., of Ottawa. The integration of the two companies will provide modern tooling facilities for the production of consumer goods.

CARPENTER STEEL

The Carpenter Steel Co., 3029 W. Bern St., Reading, Pa., has published an illustrated guide to specialty steels, covering tool and die steels, stainless steels, silicon and high nickel electrical alloys, special purpose alloy steels, valve, heat-resisting and super alloy steels, tubing and pipe in various analyses and fine wire specialties.

HONEYWELL

Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia, Pa., has published Specification Sheet 429, covering a new line of Honeywell diaphragm control valves, designated series 400.

Honeywell Specification Sheet 57 describes new two-wire thermocouples with outside diameters of $^{1}/_{8}$ and $^{3}/_{16}$ in.

INTERNATIONAL NICKEL

International Nickel Co., 67 Wall St., New York, N. Y., has published a technical bulletin, "Nickel Austenitic Ductile Irons," by F. G. Sefing.

BABCOCK & WILCOX

Carl Claus has been named director of staff of the Babcock & Wilcox Co., New York, N. Y.

DICALITE

Joseph E. Moran has been appointed assistant general manager of the Dicalite Division of the Great Lakes Carbon Corp.

NOBLE & WOOD

R. T. Barnes, Jr., 1523 Chapin Ave., Burlingame, Calif., has been appointed West Coast representative of the Noble and Wood Machine Co., Hoosick Falls, N. Y.

RELIANCE

Hamilton F. Biggar, Jr., has been appointed manager of new product development of the Reliance Electric & Engineering Co., Cleveland, Ohio.

MILPRINT

T. O. Day has been appointed works manager of Milwaukee operations of Milprint, Inc., 4200 N. Holton St., Milwaukee, Wis.

REICHHOLD

Charles C. Spencer has joined the sales staff at the Argo, Ill., plant of Reichhold Chemicals, Inc., New York, N. Y.

DIAMOND ALKALI

Diamond Alkali Co., Union Commerce Bldg., Cleveland, Ohio, has issued a checklist of Diamond literature.

TORRINGTON

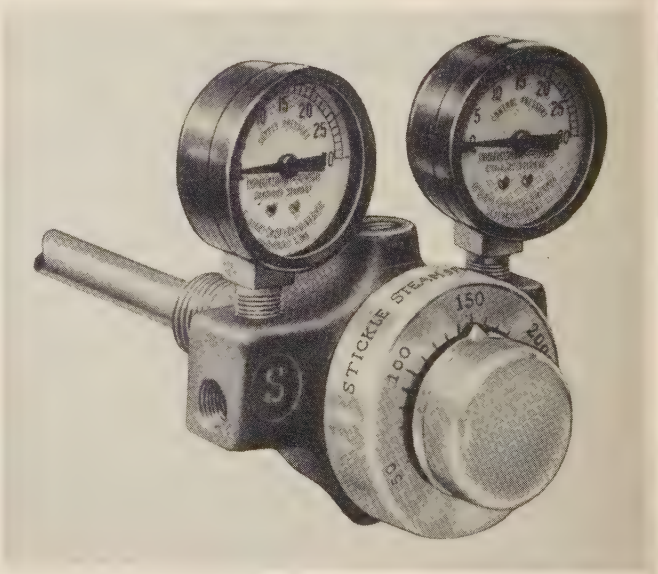
The Torrington Co., Torrington, Conn., has moved its New York offices to the Port Authority Building, 111 Eighth Ave., at 15th St.

BORDEN

Martin G. Gale has been named director of technical service for the Monomer Chemical Division of the Borden Co., New York, N. Y.

STICKLE

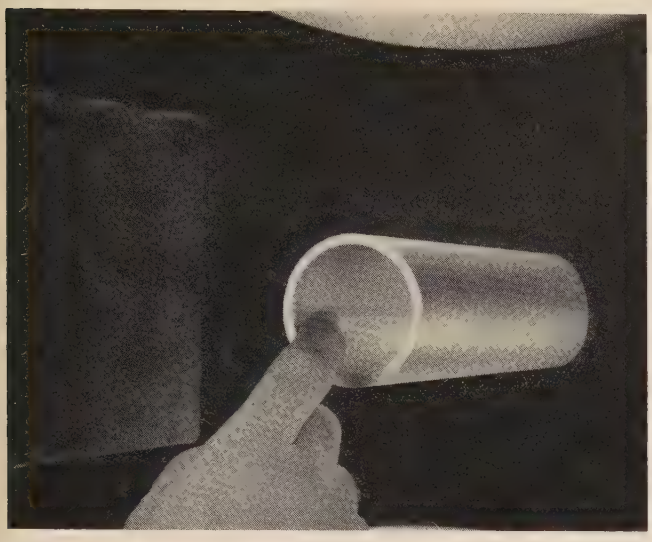
Stickle Steam Specialities Co., 2209 Valley Ave., Indianapolis, Ind., has developed a new automatic temperature control for individual driers.



Direct pilot controller on the new Stickle automatic temperature control for individual driers has dial for setting exact temperature desired on individual wet end driers. The control automatically maintains best temperature of each drier by regulating temperature of steam inside the drier

Crucible Steel

The Trent Tube Co., East Troy, Wis., a wholly-owned subsidiary of Crucible Steel Co. of America, has patented a new welding process for the manufacture of welded stainless



New pipe developed by the Trent Tube Co., a subsidiary of Crucible Steel Co. of America

steel and high alloy tubing and pipe. The new process eliminates the problem of leaving a weld bead on the inside diameter of the tubing.

Staley

A. E. Staley Manufacturing Co., Decatur, Ill., has developed a new adhesive, Staybind Waterproof Corrugating Starch No. 5030.

Research-Cottrell

Research-Cottrell, Inc., Bound Brook, N. J., has appointed Sheldons Engineering Ltd., Galt, Ont., as sales representatives in Canada, and Equipos de Proceso, S. A., Edificio International, Reforma 1-556, Mexico 1, D. F., as sales representatives in Mexico.

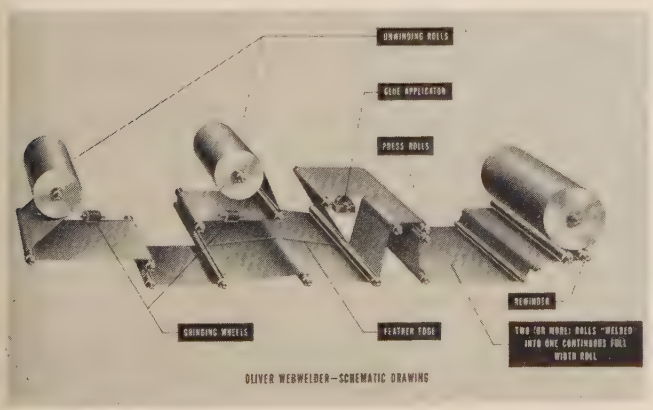
United Paper Machinery

The management of the Lockport, N. Y., paper machinery firm, formerly known as Paper Mill Stores, has announced the formation of a new and larger company to be known as United Paper Machinery Corp., 58–70 West Ave., Lockport, N. Y.

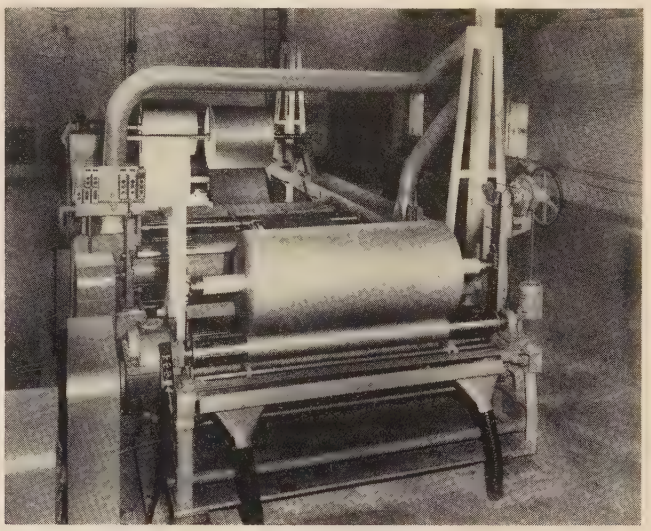
Dorr-Oliver

Richmond M. Stampley has been appointed Western Filtration Division manager of Dorr-Oliver, Inc., with headquarters in Oakland, Calif.

Dorr-Oliver has organized a new pulp and paper technical department under Ward H. Pitkin, director.



Schematic drawing of the Oliver Webwelder



General view of the Oliver Webwelder showing roll of welded stock in the foreground. The two unwinding webs being spliced are located at the far end of the machine and the panel board from which operation is controlled is shown at the left center

The company is offering the Oliver Webwelder, a new unit for splicing side rolls of paper. The unit will splice as many as five narrow rolls to produce a single finished roll up to 85 in. wide.

Herty

W. L. Belvin has been added to the staff at the Herty Foundation as assistant to director. Mr. Belvin before coming to the Herty Foundation was assistant director of research at the American Chicle Co. in New York, and before that time was head of the division of applied chemistry at Southern Research Institute in Birmingham, Ala., and prior to that time was professor of chemical engineering at the University of Arkansas.

Orthman Laboratories

The Orthman Laboratories have moved to new quarters at 407 E. Michigan St., South 312, Milwaukee 2, Wis.

OBITUARY

Donald Dale Carr-Harris

Donald D. Carr-Harris, recently assistant to the president of the Sutherland Refiner Corp., Trenton, N.J., was killed in an airplane crash in Missouri on August 4, 1955.

Mr. Carr-Harris was born in Cananaea, Mexico, on Dec. 1, 1912, and graduated as a chemist in 1934 from Western Ontario College. From 1935 to 1939 he was employed as a technician by the Anglo-Canadian Pulp and Paper Co., Quebec, P. Q. During the war he was a wing commander in the R.C.A.F. from 1940 to 1945. He was plant manager of the Woods Mfg. Co. in Ottawa, Ont., from 1946 to 1949. In 1950 he became plant engineer of the Columbia Cellulose Corp., Prince Rupert, B. C., and in 1953 he joined the Sutherland Refiner Corp.

He is survived by his wife who resides now in London, Ont.

ENGINEERING DIVISION

Special Committee Contributions

Electrical Down Time on Sectional Drives

*Final Report on TAPPI Project No. 435**

R. F. SORENSON

THE investigation of electrical down time on sectional paper machine drives was undertaken with three purposes in mind:

1. To encourage mills to keep accurate and continuous records of their electrical troubles. Such records are a great help in analyzing and controlling down time.
2. To arrive at a figure that represents the amount of down time to be expected on a sectional drive. (The data collected also indicated the probable distribution of the causes of electrical down time.)
3. To present a standard form for reporting electrical down time. This would provide a means for comparing different operations on a common basis.

COLLECTION OF DATA

Ten paper mills, representing 30 paper machines, supplied down time data for the year 1954. Data were sent in monthly through the New York TAPPI office where they were handled by code numbers. Copies of the form used in reporting down time for this project and the general questionnaire filled out for each machine are attached at the end of this report. The down time forms were received punctually and were very complete in their information.

The following tabulation lists the 30 paper machines by the product manufactured:

Kraft paper (multiwall, grocery, wrapping, and special)	9
Kraft liner board	6
Book	6
White lined, chip and jute	3
Mimeo	1
Bond	4
White envelopes	1
	30

Nineteen of these machines have electronic control and eleven have other types of position or speed regulators. Eighteen machines operate at speeds below 1000 f.p.m. and 12 at speeds above 1000 f.p.m.

DISCUSSION OF DATA

It was essential that a common unit for expressing down time be established. The unit, minutes per equivalent day, was used in arriving at the figures presented in this report. An equivalent day is the hours of scheduled production divided by 24. By this method the down time figures are averaged by the actual time the machines are scheduled to be producing. The total equivalent days of production for the 30 machines was 9493 days or the equivalent of one machine operating for over 25 years. Throughout this report, scheduled days of production are figured on an equivalent day basis.

Each of the 30 drives has been grouped according to the number of minutes down time. Figure 1 is a cumulative frequency distribution curve representing the down time distribution among the 30 machines. Fifty per cent of these machines averaged 3.6 or less min. down time per scheduled day of production. The mean (arithmetic average) of the group was 4.6 min. Approximately 64% of the machines had this down time or less. Thirty six per cent had more than average down time.

The availability of a paper machine drive operating at the mean, or 4.6 min. per scheduled day, is 99.68%.

The general questionnaire that was filled out for each machine contained information as to machine speed, paper grades number of shutdowns per year, number of operating electricians per machine, age of drive, normal scheduled hours per week, and some general details of their maintenance program. An effort was made to correlate down time with each of these factors. No correlation could be found between down time and any other factor. It seems unlikely that any correlation could be established since down time can be influenced so greatly by the efficiency of both operating and maintenance personnel. Actual component failures have no respect for the grade of paper being run or the speed of the machine.

The distribution of the causes of down time as indicated

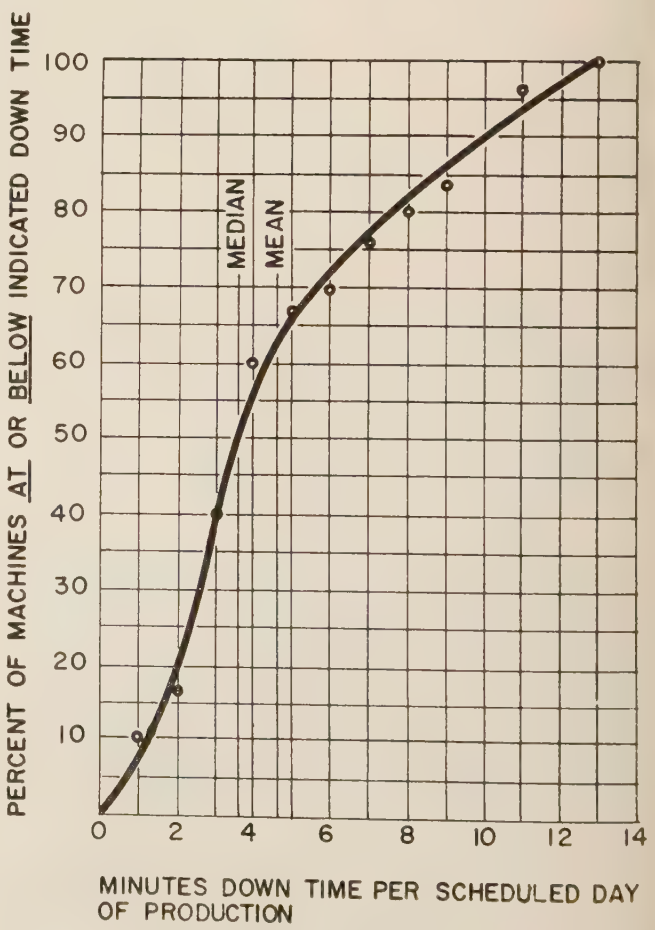


Fig. 1. Distribution of electrical down time on 30 sectional paper machine drives

R. F. SORENSON, Union Bag & Paper Corp., Savannah, Ga.

* Contributed by the Electrical Engineering Committee.

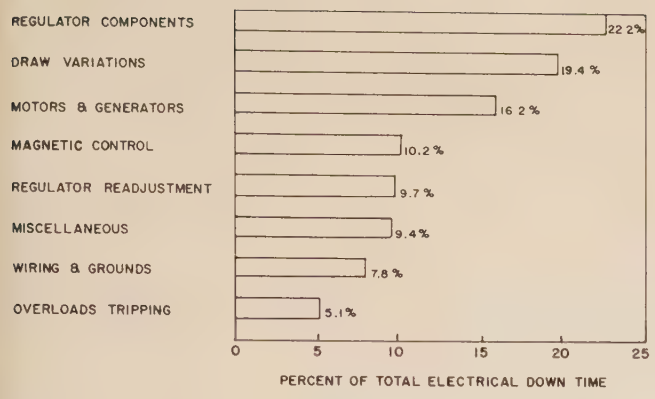


Fig. 2. Distribution of electrical down time by causes

by this survey is shown in Fig. 2. The percentages were obtained by totaling the down time from each cause and dividing by the total electrical down time. The item of "draw variations" is down time charged to the drive, but the actual cause of the trouble has not been determined. "Overload tripping" is an item generally charged to the drive, but in most cases it means that control is operating correctly in removing an overloaded motor from the line. "Regulator components" has been combined into one item since component parts vary so greatly from one type of control to another.

STANDARD DOWN TIME FORM

The accumulation of data on down time from a wide variety of machines has brought out the many difficulties in presenting a useful picture of the drives. All electric drives have certain functional parts in common. All electric drives have motors, generators, wiring, magnetic control, and all have a regulating system. The individual components that make up these functional parts may vary widely in design and theory. The purpose of this project has not been to weigh or compare the merits of the drives, but to assist the mill maintenance departments by making available average figures on down time. These figures should present a picture of the functional divisions of the drives plus other operating difficulties charged against the drive.

Figure 3 is the proposed electrical down time form of the Electrical Engineering Committee of TAPPI. This form is to be used as a monthly summary. It is assumed that information on daily down time is collected for summarizing at the end of the month. Items that are common to all drives are listed as major divisions. "Regulator components" is broken down so that the relative importance of the items that make up the regulating loop can be evaluated by the individual mill. These regulator components vary from drive to drive and are of particular interest to the mill having a given type of equipment. The total, however, is of interest to the industry. There obviously cannot be a comparison of troubles due to electronic tubes between two drives when one has no electronic tubes.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are based on the data received from the mills participating in this project:

1. The mean average electrical down time of the electrical sectional paper machine drives was 4.6 min. per day of scheduled production. Sixty-four per cent of the machines studied had less than the average.

2. Fifty per cent of the machines studied had 3.6 or less minutes electrical down time per day of scheduled production.

3. The distribution of the causes of electrical down time was:

Regulator components	22.2%
Draw variations	19.4
Motors and generators	16.2
Magnetic control	10.2
Regulator readjustment	9.7
Miscellaneous	9.4
Wiring and grounds	7.8
Overload tripping	5.1
	100.0%

4. The data showed no correlation between down time and machine speed, paper weight, type of control, etc.

The following recommendations are offered:

1. That electrical down time be discussed in terms of "minutes per equivalent day of scheduled production." (Equivalent day = total hours scheduled production ÷ 24.)

2. That the form shown in Fig. 3 of this report be used as a standard form for summarizing electrical down time.

3. That mill electrical maintenance departments should be encouraged to use the standard down time form and the other data in Figs. 1 and 2 of this report.

4. At a future date a questionnaire be circulated to determine the extent the standard form is being used. If a sufficient number of mills are using this form, the data in Figs. 1 and 2 can be revised according to the information compiled by the various mills.

Issued as TAPPI Special Report No. 406, July 26, 1955.

ELECTRICAL DOWN TIME REPORT
SECTIONAL PAPER MACHINE DRIVES

MACHINE NUMBER _____ MONTH OF _____ 19__

	TOTAL MINUTES	PERCENT OF TOTAL
REGULATOR COMPONENTS		
TACHOMETER GENERATORS		
ROTATING AMPLIFIERS		
POTENTIOMETERS & RHEOSTATS		
ELECTRONIC TUBES		
OTHER STATIC COMPONENTS		
MECHANICAL COMPONENTS		
METALLIC RECTIFIERS		
TRANSFORMERS		
MAGNETIC CONTROL		
RELAYS & CONTACTORS		
PUSH BUTTONS		
DRAW VARIATIONS *		
MOTORS AND GENERATORS		
REGULATOR READJUSTMENTS		
WIRING AND GROUNDS		
OVERLOADS TRIPPING		
MISCELLANEOUS		
TOTAL MINUTES DOWN TIME		
SCHEDULED DAYS PRODUCTION (TOTAL HRS./24)		
MINUTES DOWN TIME PER SCHEDULED DAY		

* CAUSE NOT DETERMINED

Fig. 3. Proposed form for reporting electrical down time on sectional paper machine drives

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY
155 E. 44th St., New York 17, N. Y.

LOST TIME ON ELECTRIC SECTIONAL DRIVES
(TAPPI Project No. 435)

Survey Code No. _____

Company: _____ Address: _____

General Questionnaire

Survey Code No._____

(1) Machine Number:_____

(2)

	Types of Paper	Approx. Weights	Approximate % Total Prod.	Approximate Speed Range
(a)				
(b)				
(c)				
(d)				
(e)				

(3) Number of regulated sections: _____

(4) Configuration of machines: (i.e., couch, 1st press, 2nd press, etc.)

(a)_____ (d)_____ (g)_____ (j)_____

(b)_____ (e)_____ (h)_____

(c)_____ (f)_____ (i)_____

(5) Age of drive:_____

(6) Designed speed range:_____

(7) Scheduled days of production per week:_____

(8) Number of machines in mill:_____

(9) Number of scheduled maintenance shutdowns per year: _____

(10) Number of operating electricians in paper mill:_____

(11) General description of maintenance program:*_____

(12) General description of spare parts maintenance:*_____

* (Use other side of sheet if necessary.)

Weekly Lost Time Report

(Week ending:_____)

Machine Number_____ Survey Code Number_____

	Minutes — Unscheduled lost time								
	S	M	T	W	T	F	S	Total	Remarks
Motors									
Generators									
Rotating amplifier (Amplidyne, Rototrol)									
Tachometer generators									
Relay Coils									
Relay contacts									
Push buttons									
Tubes—gas									
Tubes—vacuum									
Other static regulator components									
Regulator readjustment									
Rheostats and potentiometers									
Wiring or grounds									
Overloads tripping									
Draw variations or swinging from causes unknown but believed caused by drive									
Draw rheostats									
Mechanical components									
Misc. (please explain in remarks)									
Weekly total									

	S	M	T	W	T	F	S	Total
Scheduled maint. (man hours)								
Sched. hr. prod.								

Melting Point of Petrolatum and Microcrystalline Wax

Proposed revision of TAPPI Official Standard T 634 m-53

(THIS STANDARD IS UNDER THE JURISDICTION OF THE WAX TESTING COMMITTEE)

THIS method is the standard method of the American Society for Testing Materials (*1*) for determining the melting point of petrolatum and microcrystalline wax. It has been approved by the American Standards Association as American Standard ASA No. Z11.22-1949.

DEFINITION

The ASTM petrolatum melting point is the temperature at which petrolatum or microcrystalline wax becomes sufficiently fluid to drop from the thermometer used in making the determination under definite prescribed conditions.

APPARATUS

A. *Test Tubes.* Standard test tubes, 25 mm. (1 inch) in outside diameter and 100 mm. (4 inches) long, supplied with corks grooved at the sides to permit air circulation and bored in the exact center to receive the thermometer.

B. *Beaker.* A transparent container of not less than 500-ml. capacity which will permit immersion of the test tube to a depth of at least 75 mm. (3 inches) and will still leave a depth of 15 mm. of water below the bottom of the test tube.

C. *Test Thermometer.* An ASTM Petrolatum Melting Point Thermometer, either Centigrade or Fahrenheit as specified, graduated and accurate to 0.2°C. or 0.5°F., respectively, having a range of 32 to 127°C. or 90 to 260°F., total length 365 to 371 mm., diameter 6.0 to 7.0 mm., and conforming to the requirements for thermometer 61C or 61F as prescribed in the Standard Specifications E-1 for ASTM Thermometers. (The thermometer is obtainable from most laboratory supply companies.)

D. *Bath Thermometer.* This may be of any suitable type, accurate to 2°F. throughout the required range (40 to 220°F.).

SAMPLE

The sample shall be of sufficient size and so collected and prepared as to represent the material under examination.

PROCEDURE

Heat a portion of the sample slowly, while stirring, in a casserole or other suitable dish until the temperature reaches 200°F. or 15°F. above the expected melting point, whichever is higher, as measured with any general laboratory thermometer. (Use a fresh portion of the sample for each determination.) Remove the source of heat and let the material cool to 15°F. (8°C.) above its expected melting point. Chill the thermometer bulb to 40°F. (4°C.), quickly wipe it dry with a soft, dry cloth, and thrust it while still cold into the melted material so that approximately the lower half is submerged. Then withdraw it immediately, hold vertically away from the heat until the surface dulls, and then place it for 5 minutes in a water bath having a temperature not over 60°F.

Securely fix the coated thermometer in the test tube by means of the grooved cork so that the lowest point is 15 mm. (0.6 inch) above the bottom of the test tube. Surround the test tube with a water bath at 60°F. Raise the temperature of the bath at a rate of 3°F. per minute to 100°F., then at a rate of 2°F. per minute until the first drop of material leaves the thermometer. Record the reading of the melting point thermometer at this instant to the nearest 0.5°F. (or 0.2°C.).

REPORT

If the over-all variation of three separate determinations does not exceed 2°F. (1.1°C.), report the average of these three determinations, to the nearest 0.5°F. or 0.2°C., as the melting point of the sample. If, however, the variation is greater than 2°F., make two additional determinations and report the average of the five as the melting point.

ADDITIONAL INFORMATION

The purpose of this revision is mainly to extend the scope of the method to include microcrystalline wax and to bring the description of the thermometers into line with current practice.

LITERATURE CITED

1. American Society for Testing Materials, "Standard Method of Test for Melting Point of Petrolatum, Designation: D127-49," 1952 Book of Standards, Part 5, p. 63

41st Annual Meeting
TAPPI

Hotel Commodore, New York, N. Y.
Feb. 20–23, 1956

LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel, and Events

Empire State (Northen District)

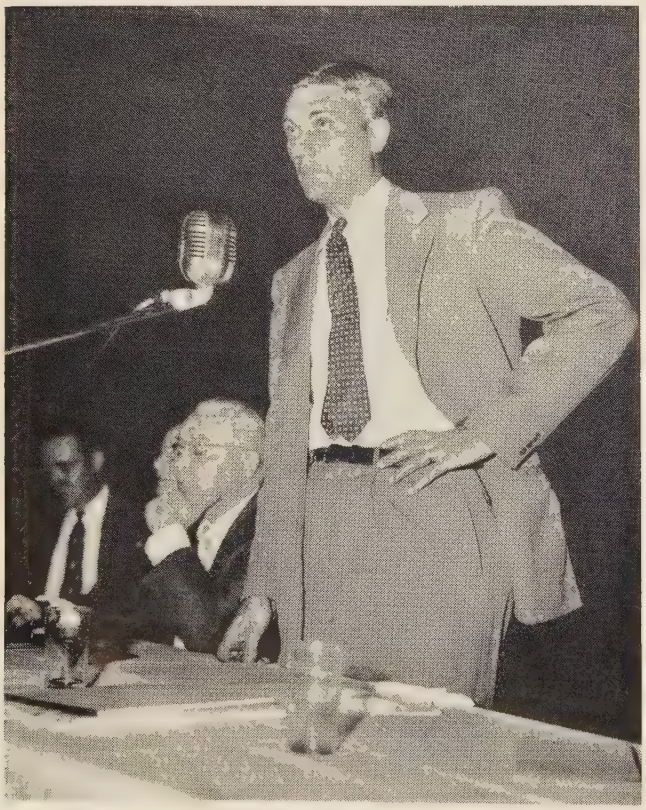
The April meeting of the Northern District, Empire State Section of TAPPI, was held on April 14, in the Hotel Woodruff in Watertown. The program consisted of the annual award paper competition. The paper presented in competition was titled "Kraft Pulping of Various Species of Hardwoods from Northern and Southern United States," by Maung Mai Aung, a student at the New York State College of Forestry at Syracuse. This paper was published in the September issue of *Tappi*. The project described in the paper was carried out by Mr. Aung at the St. Regis Paper Co., Central Technical Department, Deferiet, N. Y. Mr. Aung received a prize from the district. The program was rounded out by an interesting talk by James B. Sisson, St. Regis, Deferiet, titled "Bubbles." Mr. Sisson described various useful and not-so-useful bubble systems encountered in the industry and illustrated his talk with demonstrations of bubble formations.

The annual Ladies' Night and Peddler's party of the Northern District, Empire State Section was held on May 12, at the Hotel Woodruff in Watertown. More than 100 members and guests enjoyed a social hour, dinner, and dancing.

ELIZABETH L. CASE, *Secretary*

Ohio

The September meeting of the Ohio Section of TAPPI was held at the American Legion Home in Middletown, Sept. 8, 1955. One hundred and forty-one members and guests registered for the dinner and meeting which followed.



C. E. Brandon discussing the Ohio TAPPI Award

Vice-Chairman Ellsworth Shriver called the meeting to order by introducing C. E. Brandon who explained the Ohio TAPPI Award. The Ohio TAPPI Award is our endeavor to get the younger people in the paper industry to do research and make reports on their findings. Three top prizes will be awarded. The first prize being $50, the second prize $25, and third prize $10. All papers submitted will receive recognition.

Mr. Shriver then called on Mal Lyon, program chairman, who made the announcement of the October meeting.

Robert Boehm was then called on to introduce the speaker for the evening, Professor Jayme of Darmstadt, Germany. Professor Jayme has made an intensive optical study of wood fibers.

The title of Professor Jayme's talk was "Optical Detection of Fiber Irregularities During Sulphite Pulping." The following is a brief résumé of his talk:

Methodical dyeing experiments on wood pulps are evaluted microscopically, qualitatively and quantitatively; moreover color microphotographs serve to demonstrate morphological differences. In this way it is possible to observe several new effects besides known ones; these comprise irregularities of lignin removal during sulphite cooking, also within the same fiber, formation of lignin strands from the middle lamella, slower delignification of pressure wood cells, and raised stripes on the surface in the fiber direction.

Professor Jayme supplemented his talk with some unusual color slides which showed the irregularities very clearly.

A general question and answer period followed the talk.

VIRGIL E. PERRY, *Recording Secretary*

Pacific

The following paper was presented at the joint meeting of the Pacific Section of TAPPI and the CPPA Technical Section held at Victoria, B. C., May 21, 1955.

Continuous Chlorination of Bleach Liquor

Harry S. Fisher and Richard E. Carlson

THE continuous manufacture of either sodium or calcium hypochlorite bleach liquor is a problem which has been under discussion by interested groups for many years. A few continuous type installations have been made with varying degrees of success. The preparation of hypochlorite bleach liquor is comprised of two or three steps which can be considered separately.

The first step involves the preparation of a dilute caustic soda solution or a dilute lime slurry of controlled concentration. Most of the problems associated with continuous dilution of caustic soda to a given concentration have been solved to the extent that controlled dilution is a routine daily accomplishment. Slaking of lime follows customary procedure with subsequent continuous dilution which, while probably not such a commonplace practice as controlled automatic caustic soda dilution, can be readily achieved by means of specific gravity control.

In the second step, chlorine is introduced and reacted with the alkaline solution or slurry to a predetermined end point.

HARRY S. FISHER and RICHARD E. CARLSON, Technical Service Department, Pennsylvania Salt Manufacturing Co. of Washington, Tacoma, Wash. Presented at Western International Meeting of the Pulp and Paper Industry, Victoria, B. C., May 21, 1955.

Professor Georg Jayme of Darmstadt speaking to the Ohio Section

That the reaction can be carried on continuously under automatic control and to a highly satisfactory degree will be shown later.

The third step which applies only to calcium hypochlorite liquors concerns clarification. While clarification of continuously produced calcium hypochlorite bleach liquor will not be extensively discussed here, several methods are known which offer possibilities for incorporation in a continuous process for producing a high quality bleach liquor.

One of our chlorine producing plants utilized its tail gas containing chlorine, air, carbon dioxide, and hydrogen to chlorinate an alkaline solution. Inasmuch as the gas mixture varied in volume and ingredient concentrations, an automatic device was required to control a flow of alkaline solution proportional to the variable chlorine content in the reaction system. One of the methods proposed for controlling this reaction was by temperature differential since the reaction is exothermic. Chlorination of either sodium or calcium hydroxide will liberate enough heat energy to raise the solution temperature about 1°C. for every 3 grams of chlorine added per liter of solution. Therefore, if a bleach liquor of approximately 30 grams per liter available chlorine is prepared, the temperature during the chlorination process will rise about 10°C. or 18°F. Only the end portion of the temperature differential can be used for control purposes, and the accuracy of control is restricted by the limits within which small increments of temperature change can be measured. The primary objection to this method of control was that it offered no self-correcting principle under conditions of varying alkaline solution concentration supplied to the system.

It was also thought that pH measurement offered possibilities for regulation of the controlled variable. Experience has shown pH measurement to be feasible for controlling the alkali-chlorination end point using glass electrodes in solutions of high sodium ion content. However, it was determined that the pH remains at a high level with no appreciable change for control purposes until the reaction has proceeded to the point where insufficient excess alkali remains to provide adequate stability of bleach liquors. It may be of interest to note that the reaction has been controlled from pH 8 to pH 9 within which range excess alkali is, for all practical purposes, nonexistent.

The most satisfactory control method found in this investigation for continuous manufacture of bleach liquor employs oxidation-reduction potential. It is believed that D. J. Pye in his report on "The Control of Bleach Manufacture by Oxidation Potential" in the *Journal of the Electrochemical Society* for August, 1950, was one of the first to suggest this method. Pye, using a 1.1-v. potentiometer measured the electrode potential of a platinum-saturated calomel cell in different strengths of sodium hypochlorite solutions containing varying amounts of excess alkali. The results were plotted as curves illustrated in Fig. 1. Pye also reported successful substitution of a silver electrode for the calomel electrode with only a minor change in electromotive force for the cell.

In the first phase of this investigation, a series of measurements was made patterned on Pye's work. For the purpose of simplification, a vacuum tube voltmeter was used in place of a potentiometer for making voltage determinations. Since the vacuum tube voltmeter draws some current through the electrode circuit, some polarization of the electrodes occurs and although reproducible results could be obtained with the platinum-calomel cell, the e.m.f. values were somewhat lower than reported by Pye. It was found that a silver electrode could not be used because of polarization but a platinum, silver-silver chloride cell gave satisfactory and reproducible results.

For the reaction, 50% commercial liquid caustic soda was diluted and then chlorinated in stages. The oxidation-reduction potential was measured and the excess alkali and available chlorine titrated at each stage. For comparison, a solution using reagent grade sodium hydroxide was prepared and chlorinated in the same manner. Curves were drawn plotting electrode potential against excess alkali as shown in Fig. 2. The values for reagent grade sodium hydroxide and dilute liquid caustic solutions of approximately the same concentrations vary more than would normally be anticipated from the slight difference in concentration. Since it is known that the presence in the solution of greater or lesser amounts of impurities such as chloride, carbonate, and heavy metal ions affects the net oxidation-reduction system under the conditions as measured, this departure from the expected variation is believed to be due principally to the difference in composition of the commercial caustic and the reagent grade caustic soda. Only those portions of the curves considered to be of value for the application under discussion are shown in Fig. 2. These curves have the same general characteristic form as those prepared by Pye but are shifted downward along the ordinate. Although the curves for various concentrations appear only laterally dispersed, no simple correction could be found to cause superimposition and justify indication of a single set of data. It was thought that the effect of the temperature rise from heat of reaction on the oxidation-reduction potential should be determined. Accordingly, a caustic soda solution of known concentration was divided into two portions and

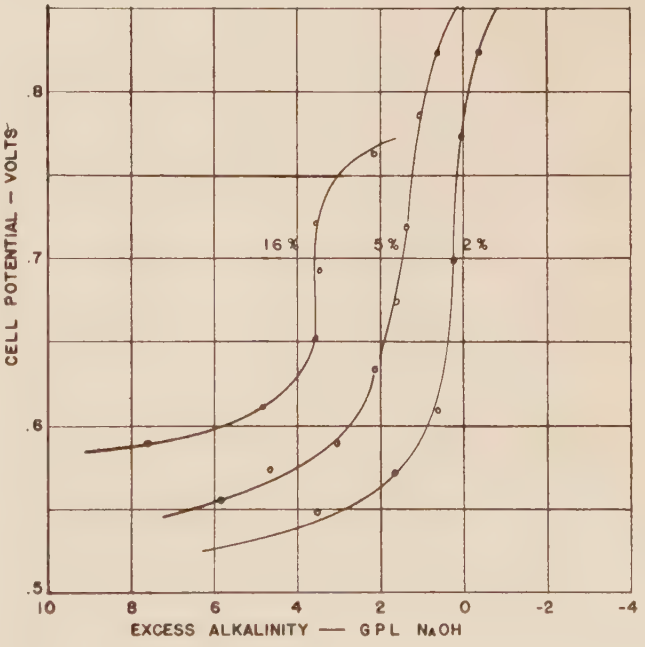


Fig. 1

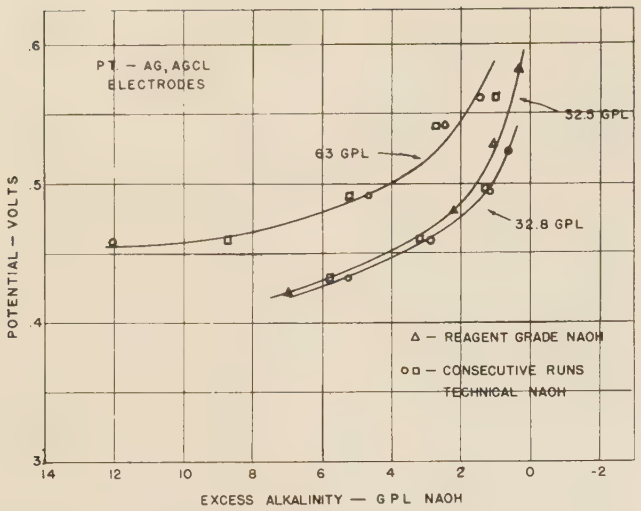


Fig. 2

chlorinated with temperature control with a constant temperature bath on one and no temperature control on the other. It was found that the difference in potential due to the increase in temperature was so minor that for practical applications it could be neglected.

The lime-chlorine system was investigated in the same manner as the caustic soda-chlorine system starting with commercially hydrated lime slurries of known concentrations. The results as shown in Fig. 3 are plotted in terms of electrode potential against grams per liter of available chlorine instead of excess alkali, because in calcium hypochlorite bleach some lime remains undissolved and, therefore, available chlorine has greater significance as a control factor.

With the data obtained, it was possible to consider some of the requirements of a system utilizing the oxidation-reduction potential method for controlling the manufacture of bleach liquor. These were:

1. Some method of mixing the chlorine and alkali in such a manner that rapid reaction results.
2. Electrode placement so that sensing of changes in the reaction system occurs with as little time lag as possible.
3. Measurement of electrode potential as accurately as possible. Since the electrodes are subject to polarization, this means measurement with as near zero current flow as can be readily accomplished.
4. Conversion of the potential measurement into control of either the chlorine or caustic soda flow.

When starting the design of a pilot plant unit for this work it was possible to proceed with some experience. Prior to this investigation a pulp mill met difficulty with the manufacture of bleach liquor. The problem required immediate solution and would not permit the delay attendant upon construction of conventional facilities. The mill was able to use unsettled calcium hypochlorite bleach and consequently a successful continuous system was installed which employs manual control of both lime and chlorine supply. Later, density control of the lime slurry was added to improve the operation of the installation.

Pilot plant operations were initiated using what seemed to be the simplest method of intimately mixing chlorine with dilute alkaline solution. Dilute caustic soda and chlorine gas were mixed with an ejector and the length of the ejector tail pipe and flow rates changed to vary the retention time of reactants before the product was discharged into a vessel. Caustic soda was diluted to provide a bleach liquor containing approximately 30 grams per liter of available chlorine. Retention times based on liquid flow were varied from 10 to about 40 sec. but it was not found possible to obtain satisfactory absorption and reaction of the chlorine at any time. This indicated too slow a reaction rate to be practical. It has long been known that reaction of chlorine and alkali to form hypochlorites requires an induction period. This suggests that the reaction is of a complex nature in the autocatalytic class. Following the induction period the rate of reaction increases rapidly to equilibrium. On this theory the pilot installation was modified by replacing the ejector with a flooded reaction tower or column so arranged that the alkaline solution and chlorine could be fed into the bottom of the tower and the bleach solution taken off near the top, thus providing an opportunity for an intimate mixture of alkali, chlorine, and reaction products to be present in the reaction area. Under constant flow conditions the reaction proceeded satisfactorily and equilibrium was established; but under changing flow of the reactants, equilibrium was disrupted and the product was found to vary qualitatively and quantitatively. The difficulty was overcome by installation of a draft tube which accomplished the desired rapid mixing of the reaction components within the tower. Final design of the pilot plant unit is as indicated in Fig. 4.

The reaction tower was a length of 4-in. diameter transite pipe with overflows so arranged that the total height of the reaction column could be varied. The oxidation-reduction electrodes were inserted through openings in the sides of the column in such manner that they were diametrically opposite and in the same plane. The electrode gap approximated 2 in. The location of the electrodes in the tower could be altered to determine the proper sensing point. Gaseous chlorine was passed through a pressure control valve, rotometer, and a flow control valve operated by the potential control instrument. The chlorine injection point at the bottom of the tower was so designed that a rising current is produced inside and a descending current outside the draft tube. The alkaline solutions were pumped into the bottom of the reaction tower and controlled through a manual valve calibrated to give approximate rates of flow.

Flow rates were varied from an arbitrary minimum of 6 to 18 g.p.m. It was found that if the caustic flow rate was increased or decreased slowly, excellent chlorine control was maintained throughout the flow range. However, if the flow rate was changed abruptly by several gallons per minute, slow response resulted in the low flow range and oscillation or hunting in the high range flow. In making bleach, the system was adjusted to chlorinate to a fixed amount of residual alkalinity. In the case of bleach of approximately 30 grams per liter available chlorine the system was set first at 5 grams per liter excess caustic alkalinity and then decreased by steps to 0.7 gram per liter. Residual alkalinity could be held within 0.1 gram per liter at any setting but below 1.5 grams per liter the system became unstable under changing flow conditions result-

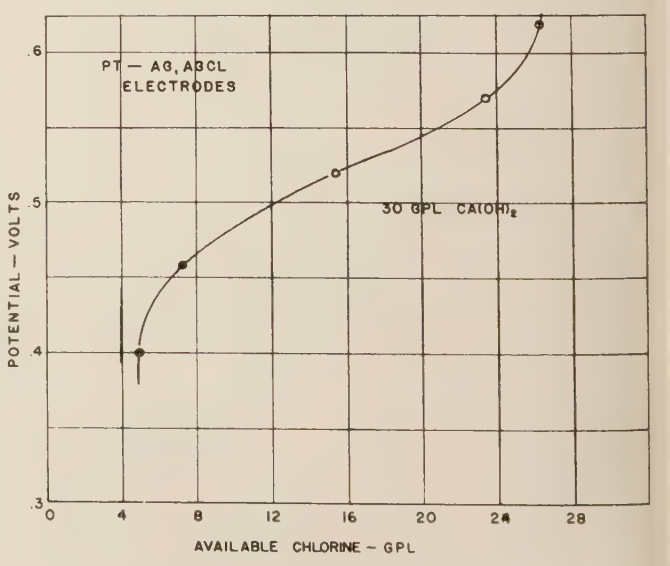


Fig. 3

ing in oscillation with no return to control. Similarly, when bleach strength was increased to approximately 60 grams per liter available chlorine, system instability and loss of control under changing flow occurred below 3 grams per liter excess caustic. At 1.5 grams per liter excess caustic for 30 grams per liter available chlorine bleach, or at 3 grams per liter excess caustic or above for 60 grams per liter available chlorine bleach, oscillations or hunting occurred only from an abrupt decrease in caustic flow with return to normal control within approximately 2 min. Under changing flow conditions excess caustic variation averaged within 0.2 gram per liter for any setting, and 0.15 gram per liter for constant flow, even with the limited control equipment used.

After these operating characteristics were established, the system was changed to chlorination of a lime slurry. As might be expected from the curve shown representing this reaction, control closely followed production of sodium-base bleach liquor. Agitation within the reactor was sufficient to keep the lime in suspension until chlorinated. Runs were made in the range of 30 to 32 grams per liter available chlorine with flow rates of 9 to 12 g.p.m. Commercially hydrated lime was used and alkali utilization approaching 100% was obtained.

Although the results from the operation of the pilot unit were gratifying even with the limitations of the control equipment used, it is known that improved control could be attained by further modification of the instrument control system. For this work output from the electrodes was coupled directly to the input of the control instrument even though the instrument had not been specifically designed for such an application. The input impedance of the controller was not sufficiently high to prevent current drain in the electrode circuit. Polarization of the electrodes from passing current in the electrode circuit reduced the effective controlling range of the instrument.

A study of the oxidation-reduction potential curves will serve to show what requirements must be met by a potential

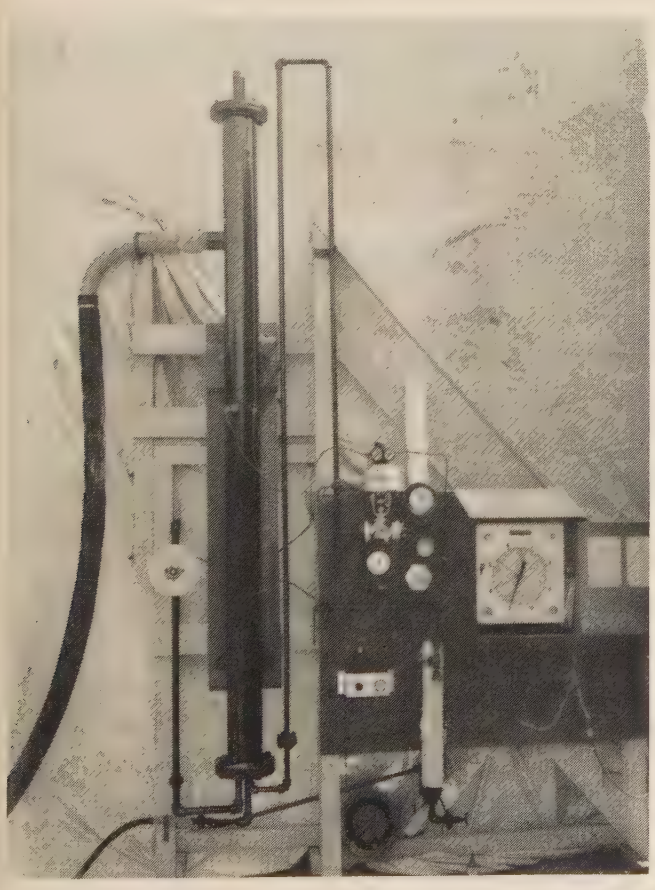


Fig. 4

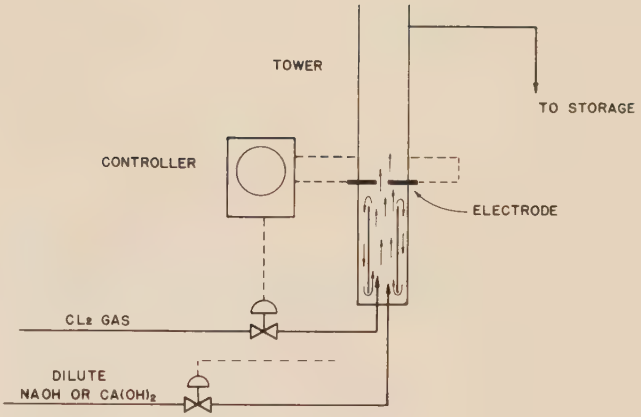


Fig. 5. Continuous chlorination of bleach liquor

operated flow controller. It can be observed that as zero alkalinity is approached, the slope of the curve becomes very steep. If the reaction is to be controlled at approximately 2 grams per liter excess alkali or higher, the control range will fall along the flatter portion of the curve and control will be quite readily achieved even though the flow rate or alkali concentration is changed. On the other hand, if it is necessary to control the reaction near the stoichiometric end point, or in the range from 1 gram per liter excess to 0 gram per liter excess alkali, a potential operated control instrument will be receiving for any system variation a high rate of e.m.f. signal change with respect to the rate of change of excess alkali; thus, the control instrument would tend to produce large changes in chlorine flow at the critical point of control. Some means of dampening the changing impulse sent to the control valve when operating in this high e.m.f. change area is therefore indicated. Such a device may take one of several forms and be incorporated into the controller.

With pilot plant work accomplished on a scale which approaches the bleach liquor requirements of many pulp mills, and by which method it is believed bleach liquor of consistently satisfactory quality can be produced, the schematic diagram shown in Fig. 5 is suggested as a pattern for continuous production in mill installations where benefits might be derived from the continuous chlorination of bleach liquor. It is felt that a small amount of storage for bleach liquor between manufacture and use is very desirable if not strictly a necessity. Level measurement of the stored bleach liquor applied to throttling control of the alkali feed would serve to maintain the rate of bleach liquor production in keeping with consumption thus avoiding sharp fluctuations in quality which might be attendant upon rapidly changing flow rates, or start and stop operation. Chlorine gas would be applied through the usual operations of vaporization, pressure, and flow control. Even though chlorine gas produces a slightly higher temperature rise than liquid chlorine, gas should be used because metering and controlling flow of liquid chlorine with sufficient accuracy are difficult. A properly designed mixing chamber with instrumentation which will sense and control potential between two properly placed electrodes completes the installation. With proper design and operation, all chlorine gas is reacted and the only odor is that typical of bleach liquor. The various factors affecting the size and design of the reaction equipment would be dependent on the requirements of any specific installation.

Continuous automatic production of sodium bleach liquor is a reality. The production of clear lime bleach liquor requires the additional step of clarification of the turbid liquor discharge from the chlorinating tower. Investigation reveals that several steps can be taken to clear the liquor of turbidity. Initially, side hill fine screening or centrifugal separation of grit particles from the lime slurry is advantageous. The finished bleach liquor can be put through a continuous gravity

clarifier or a centrifugal separator. The washing of the sludge to save alkali and chlorine values can follow the procedure above with the wash water going to dilute the incoming lime to the system.

The authors wish to thank Messrs. Graham and Hall of the Minneapolis-Honeywell Regulator Co. for making available the control instrument for this work and for technical advice on instrument application.

LETTERS TO THE EDITOR

Ammonium Bisulphite Pulping

To the Editor, *Tappi:*

As an overseas member of your Association I write to ask if you could give me some information about ammonia-base sulphite pulping. I have read the articles in *Tappi* and I find the whole problem very interesting.

If we find that ammonia-base sulphite pulping seems to be of great value to us, it is possible that I shall make a journey to U.S.A. to study the process at some mills. Ammonia is however very expensive in Sweden, compared with calcium, and it is therefore necessary to reduce the ammonia consumption as much as possible through recovery or to utilize the spent liquor.

At our mill we are making strong unbleached sulphite pulp. For that reason I would be very thankful if you could give me a list of the sulphite mills using ammonia base for making strong unbleached sulphite pulp. I should also like to obtain some information about recovery of chemicals and spent liquor utilization.

Karl Fredrik Gustafsson
Sulphite Superintendent
A/B Stjernfors-Ställdalen
Ställdalen, Sweden

To the Editor, *Tappi:*

The following tabulation represents, to the best of our knowledge, those mills in North America which are currently using the ammonia-base process. Included also is the estimated production of pulp in tons per day, and the year in which conversion to ammonia-base pulping was completed.

United States		
Rayonier, Inc., Shelton, Wash.	300	1945
Eastern Corp., S. Brewer, Me.	155	1947
Eastern Corp., Lincoln, Me.	90	1948
Crown Zellerbach Corp., Lebanon, Ore.	55	1949
Wausau Paper Mills Co., Brokaw, Wis.	90	1950
Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis.	140	1951
Rayoner, Inc., Hoquiam, Wash.	400	1952
Columbia River Paper Mills, Vancouver, Wash.	110	1952
Scott Paper Co., Anacortes, Wash.	100	1952
Scott Paper Co., Everett, Wash.	310	1954
Canada		
Fraser Co., Ltd., Edmundston, N. B.	350	1953
Restigouche Co., Ltd., Campbelltown, N. B.	260	1954
Irving Pulp & Paper Co., St. John, N. B.	150	1954
Canadian Internatl. Paper Co., Gatineau, Que.	180	1954

In addition to the above, Groveton Paper Co of Groveton N. H. will be converted to ammonia-base pulping this year. Also, Charmin Paper Co. of Green Bay, Wis., is planning a trial run on ammonia-base pulping early this fall.

We are not aware of any installation where recovery of ammonia has been possible. There is the possibility that spent ammonia-base liquor can be effectively used in the production of yeast to at least lessen the quantity of ammonia purchased on the outside for this use.

For a general bibliography on ammonia-base pulping, our suggestion would be *Tappi*'s January, 1954, issue.

Frank E. Eck
Product Sales Supervisor
Industrial Chemicals
Spencer Chemical Co.
Kansas City, Mo.

Paper Statistical Quality Control

To the Editor, *Tappi:*

Since the last time I saw you at one of our seminar meetings at New York University I finished a most successful trip around the world installing quality control methods in paper mills, paper converting plants and printers.

The Jujo Paper Manufacturing Co. submitted a 28-page report to me which had been printed for their foremen-management group which showed that in the mill in Tokyo where there are six machines they increased their production 9.2% and their yield out of the finishing room was 11.6% greater in the months of April and May as compared to the same figures of October and November, 1954. This installation has now spread to their other five mills involving some 23 paper machines so that by this time the installation is well on its way.

I also visited paper mills in Italy and France, in fact, two paper manufacturers in Paris attended my seminar in conjunction with their paper converting accounts.

I pass these notes on only with the idea that I am sure that you are always interested in learning of the expanded uses of new techniques and developments.

I assure that the support that the TAPPI publications and the Association, in general, have given to this general problem of statistical quality control is most appreciated, not only by my ideas, but by technicians around the globe. Please keep up the sound and solid editorial techniques with which you have been so successful.

Donald Macaulay
Paper Quality Control, Inc.
Chappaqua, N. Y.

Coefficient of Friction of Paper

To the Editor, *Tappi:*

Our plant librarian has informed me that you may be able to help us on a problem which we have. The problem is this: We would like to know what the coefficiency of friction is of paper on steel, stainless steel, brass, chrome plated surfaces, and wood (with waxed surface).

Edwin D. Aspengren
Mechanical Research and
Materials Testing Labs.
Meredith Publishing Co.
Des Moines, Iowa

To the Editor, *Tappi:*

The following references to the coefficient of friction with paper may be of use to Mr. Aspengren:

Turk, John G., and Maxon, Richard, "The G.C.M.I. Friction Tester—an Instrument for Measuring Coefficients of Friction of Paperboard," *Tappi* 38, No. 5: 161A (May, 1955). (Used to determine static and kinetic friction of paperboard on paperboard.)

Broughton, Geoffrey, and Gregg, John L., "Some Observations on the Kinetic Coefficient of Friction of Paper," *Tappi* 35, No. 11: 489–493 (Nov., 1952). (Determined coefficient of kinetic friction of bond paper on copper, 0.36; bond paper on lucite, 0.23; and various papers (bond groundwood,

onionskin, kraft wrapping, blotting, coated, book) on themselves, 0.45 to 0.67 depending on machine direction, wire, and felt sides; also determined that coefficient of paper on copper increased with relative humidity, beating, rosin content, and filter content and decreased on medium calendering and with the addition of fats and paraffin.)

Delcroix, Pierre, "Coefficient of Friction of Papers," *Bull. Assoc. Tech. Ind. Papetière* (1) No. 1: 12 (March, 1947). In French. (Found that coefficient of friction of paper on paper about that of wood.)

Dreby, Edwin C., "A Friction Meter for Determining the Coefficient of Kinetic Friction of Fabrics," *J. Research Natl. Nur. Standards* 31: 237–246 (1943). (Original of friction meter used by Broughton and Gregg.)

T. W. Lashof, *Paper Section*
National Bureau of Standards
Washington 25, D. C.

Peroxide Solutions

To the Editor, *Tappi:*

We should like to receive your advice about a problem which occurred in our mill during the manufacture of peroxide solution.

For the bleaching of wood pulp we use Na_2O_2. The solution contains 18 g./1. Na_2O_2, 13 g./1. H_2SO_4, 40 g./1. waterglass. The pH is 11–11.5.

The hardness of the used water is about 5° German hardness.

Now we have trouble with a flocky, light yellow colored sediment which is formed a few hours after the manufacture and will clog the pipe's (rustless steel) in the long run.

Van Gelder Zonen N.V.
Renkum The, Netherlands

To the Editor, *Tappi:*

In the letter from Van Gelder Zonen N.V., it is stated that the bleaching solution contains: 18 g./1. Na_2O_2, 13 g./1. H_2SO_4, and 40 g./1. waterglass.

Most Na_2O_2 contains some iron, even if only a very small amount. This iron will precipitate unless the bleaching solution is made correctly. It is not surprising that a light yellow colored flocky sediment is formed if the bleaching solution is made up in the sequence outlined above.

In order to overcome the difficulty encountered by the Royal Paper Mills, I suggest that the bleaching solution be made up as follows:

Dissolve the sodium silicate solution and make up the total solution to perhaps 80% of the total volume desired. Add the sodium peroxide at this point, while maintaining good agitation. After the sodium peroxide is in solution, slowly add the required amount of sulphuric acid to the agitated solution. Additional water is then added to bring the bleaching solution to its required volume.

In order to help stabilize peroxide solutions we have found the addition of some magnesium sulphate helpful. If this material is used, it must be dissolved in the water before the addition of the waterglass.

N. J. Stalter, *Manager*
Peroxygen Products Development
E.I. du Pont de Nemours & Co., Inc.
Wilmington, Del

Pulp Testing Terms

To the Editor, *Tappi:*

Recently I have been trying to make some comparisons of pulp strength figures obtained by American testing methods and by British methods. I have applied both to the technical section of the British Paper & Board Makers' Association and to the British Paper and Board Industry Research Association for information on making such comparisons. I was quite astonished to find that such information is not readily available.

We were concerned with an article in *Tappi*, a reprint of a paper presented at the ECLA/FAO/TAA Latin American Pulp & Paper Meeting, Vol. 37, No. 12, December, 1954, in which a sample of pulp from a nonexistent Celdecor mill is compared with pulps made by the mechano-chemical process in U. S. laboratories. As mentioned, the mill quoted does not exist and so we were concerned to find some comparative figures and put them on the same footing as those quoted, but we ran into a great deal of difficulty in making the conversions. I wonder if you can help us with conversion figures for converting to the metric system which is used in the TAPPI standards, and our own standards, the following: bursting strength, points per ream—lb. × 100; tearing resistance, g. per ream—lb. × 100; tensile strength, g. per ream—lb.

We enclose the lines along which we have worked to make our conversions, but we should appreciate confirmation as to whether these conversions are valid. We are particularly doubtful over the tear factor.

As a matter of fact, we contacted quite a number of people seeking this information, and the unanimous feeling was that they were scarcely the sort of unit that one would associate with an article in *Tappi*. One is, therefore, confronted with the probability that no one beyond the United States and Canada is able to comprehend the figures. Would it not be possible for *Tappi* to insist that its contributors use TAPPI standard terms of expression, in such a standardised field as pulp evaluation?

C. B. Tabb, *Chief Technician*
Hatch End, Middlesex, England
Cellulose Development Ltd.

To the Editor, *Tappi:*

The figures presented in the tables to which Mr. Tabb makes reference can readily be converted to metric units through use of the factors presented in TAPPI standards T 220 m-53. Since use of basic weight in English units is rather common practice and also suggested by TAPPI, this may at times lead to some confusion. At this branch hand sheets prepared in a British sheet mold contain about 1.2 grams of pulp on a moisture-free basis. Values presented in the tables have been corrected to the same basis weight.

To assist you we are presenting the methods by which the various physical characteristics have been calculated and also the factors necessary for conversion to metric units.

Basis weight: pounds per ream of 500 sheets 25 by 40 in.

$$\text{Bursting strength: } \frac{\text{Mullen value, p.s.i.} \times 100}{\text{basis weight}} = \text{points/ream-lb.} \times 100$$

Burst value is converted to metric units, grams/sq. cm., by multiplying by 0.5

$$\text{Tensile strength: } \frac{\text{breaking load, kg. on 15-mm. strip}}{\text{basis weight}} = \text{grams/ream-lb.}$$

Tensile value is converted to metric units, breaking length in meters, by multiplying by 47.48

$$\text{Tear resistance: } \frac{\text{force in grams to tear single sheet} \times 100}{\text{basis weight}} = \text{g./ream-lb.} \times 100$$

Tear factor in metric units is obtained by multiplying by 0.711

T. F. Clark, *Acting Head*
Agricultural Residues Section
Northern Utilization Branch
Peoria, Ill.

Pulp Light Scattering Coefficients

To the Editor, *Tappi:*

I would like to inquire if any TAPPI information is avail-

able on the scattering coefficient as used in pulp testing and a standard method for its determination.

ANTON J. HAUG
Nashua, N. H.

To the Editor, *Tappi:*

I know of no TAPPI method for the determination of the light scattering of pulp. In the *Paper Trade Journal* for Jan. 6, 1938 (Vol. 106, TS 5), D. B. Judd published a paper "Optical Specification of Light-Scattering Materials." In this paper, he shows how the Kubelka-Munk theory can be applied to various types of paper. If one could prepare pulp handsheets of controlled thicknesses, he could apply the procedures described by Mr. Judd to pulp.

It might also be possible to evaluate a relative sort of light scattering of pulp while it is suspended in water. This would be more the type of method used in the plastics industry for polymer-molecular evaluations. However, it is necessary, in molecular determinations, to have the individual molecules completely disbursed in the suspensoid. Since pulp fibers consist of large agglomerates of cellulose molecules, it is not possible by light scattering methods applied to pulp suspensions to determine characteristics of the molecules present.

RICHARD S. HUNTER, *Secretary*
TAPPI Optical Properties Committee

RECENT BOOKS

Pulp and Paper Manual of Canada—1955. Gardenvale, P. Q. 1955. Buckram, $8^1/_2 \times 11^1/_2$, 440 pages. $7.50.

The 25th annual manual is Canada's perennial annual catalog and contains useful information relating to the design, operation, specification, and purchasing of paper mill supplies.

Although it is essentially a catalog, each volume contains a number of valuable articles. The present volume includes flow charts of Canadian pulp and paper mills, engineering tables and charts on such subjects as conveyor belting, equivalents of measure and articles on sawmill waste, equipment for barking and chipping, and other subjects.

Handbook of Engineering Materials. Edited by Douglas F. Miner and John B. Seastone. John Wiley & Sons, New York, 1955. Pyroxylin. $5^1/_2 \times 8^1/_2$, 1090 pages. $17.50.

To the experienced plant engineer a new handbook dealing with any aspect of engineering is welcome. The present volume features four broad classifications: General Information on Materials (Materials Specifications); Metals; Nonmetals, including wood, paper, fibers, plastics, rubbers, fuels, lubricants, and industrial chemicals; and Construction Materials, including timber, foundations, cementing materials, weather, and moisture protection.

The section on paper is interesting. It includes information on electrical insulating paper, papers for protective applications, inorganic papers, classification of fibers, properties of fibers, etc.

The book, like other similar handbooks is of great value and can save the user from unnecessary effort in seeking information about materials.

Note: Books reviewed in these columns may be obtained through the Book Department of the Technical Association of the Pulp & Paper Industry, 155 E. 44th St., New York 17, N. Y.

EMPLOYMENT SERVICE

POSITIONS WANTED

E317-55. Manager or Assistant to President. More than twenty years' background in fine and specialty papers. Experience in technical and quality control, production line supervision, and general mill management. Ability in setting up production, cost, and purchasing control systems.

E318-55. Chemist: 36, married, fifteen years' experience laboratory supervision, development of coating pigments and coating, and technical development on fourdrinier machines. Now employed as operating chemical engineer responsible for technical supervision and development on fourdrinier machines. Desire position in technical development or operating supervision in East or South.

POSITIONS OPEN

P474-55. Research Chemist or Chemical Engineer—for group leader in research laboratory of Wisconsin kraft pulp and paper mill. Prefer man with 2 to 5 years' experience in technical phases of pulp and papermaking, but not necessarily kraft. Salary commensurate with experience. Replies held in strict confidence.

P475-55. Paper Chemist, with paper mill experience, graduate of a university specializing in paper curriculum preferred, desired for laboratory of national organization serving paper industry. Work includes research and development work on specialty products such as beater additives, sizes, coatings. Reply with full details of education, experience, salary requirements. All replies confidential.

P477-55. Coating Engineer. Expanding Pacific-Northwest wood products company requires research engineer, age 23 to 29. Graduate chemistry, chemical engineering, or wood technology. Education and/or experience in coatings or paint technology. Experience in emulsion or water-based systems particularly desirable. Responsible for coatings development program. Send résumé. All replies held confidential.

P479-55. TAPPI Staff technical service man to assist Association Secretary. At least five years' experience in operating, engineering, or technical department of a pulp and paper company desirable. Must be industrious, enthusiastic, and able to get along well with people. Ability and interest in writing needed. Considerable travel involved. Broad interest in the many branches of the industry important. Give résumé of education and experience and statement indicating in what ways you feel that you can be of best service to the Association as an employee. State salary expected.

P487-55. Technical Director. Excellent opportunity for Chemical Engineer to supervise all phases of technical control and development work in 70-ton board mill. Must be a man with experience in the board industry with ability and initiative. Work would include certain phases of production and mill engineering. Midwest location. Send résumé of experience, education, and salary requirements. Good opportunity for advancement to management.

P488-55. Sales-Service Engineer Wanted. Man with good background in groundwood or chemical pulp manufacturing. Semichemical pulping experience especially valuable but not required. Excellent and unusual opportunity to learn about new pulping processes and new pulping equipment. Considerable travel involved. Good starting salary depending upon experience.

P489-55. Sales Engineer Wanted. Challenging position for high quality individual interested in selling for old established firm manufacturing refiners, continuous digesters, and other pulp mill equipment of excellent reputation. Oppportunity for varied experience in new pulping processes and machinery development. Considerable travel involved, of course, but an excellent starting salary plus bonus with prospects of high earnings is offered. Experience in mechanical and/or chemical pulping desirable. Semichemical pulping experience especially desirable.

P491-55. Positions for Paper Executives. The Nation's largest executive placement agency has an exclusive department for the nationwide placement of successful engineers, technical men, and salesmen in the paper industry. Immediate openings in all parts of the country for men under 48 earning over $7000. Write to R. Graebner, Graebner Executive Exchange, 116 S. Michigan, Chicago, Ill.

PAPER CHEMIST

Paper Chemist for research and development with a large electronics Division of General Motors. The position is permanent and many desirable benefits are offered, such as: location in progressive and pleasant Indiana city, excellent working conditions, outstanding G.M. employee benefits, and a good starting salary. A degree in chemistry or chemical engineering, and 5 years' experience in paper industry required.

Reply to TAPPI, P476-55, 155 E. 44th St., New York 17, N. Y.

QUALITY CONTROL SUPERVISOR

A nationwide paper board manufacturer is considering applicants for its Eastern Massachusetts and Western New York mills. Applicants should have statistical quality control experience, chemical training and experience in the paper field. Knowledge of printing and carton manufacturing helpful. Successful applicant will be in charge of Plant Laboratory and will have customer contact. Reply to *Tappi* P492-55.

GRADUATE CHEMIST
or
CHEMICAL ENGINEER

with education and experience fitting him for research on paper products. Opening is in an established company making paper for board, felt for roofing and floor covering and pulp molded products. Salary commensurate with education and experience. In reply state experience and salary expected. Reply to Tappi, P494-55, 155 East 44th St., New York 17, N. Y.

WANTED

Assistant to Technical Director

Expanding speciality mill located in Southern New England has a challenging position for a Chemist or Chemical Engineer. Wonderful opportunity for the right man. Must have ability to supervise technicians, do trouble shooting, and development work. Under 35 years of age; Salary open. Send résumé of personal background, work experience, and present salary to Tappi, P495-55, 155 East 44th St., New York 17, N. Y.

P493-55. Chemist or Chemical Engineer. Young. Experience not essential. Cylinder specialty mill located in central eastern New York State.

P496-55. Paper Chemist. At least two years' experience with paper coatings, adhesives, resins, or development of chemicals for the paper industry. Fine opportunity with established chemical firm in large eastern city.

MISCELLANEOUS

A13-55. Are your Mullen tester readings correct? Standardized aluminum foil in ranges 10–15, 25–35, 40–50, and 55–65 lb. available from Testing Foil Service, 304 N. Stevens St., Rhinelander, Wis.

A14-55. Manufacturer's Representative—Covering the corrugated and boxboard, paper converting, and plastics industries. We offer an outstanding line of edge alignment controls to supplement your present line of machinery products.

MARKET DEVELOPMENT

Excellent opportunity for paper chemist preferably with experience in promotion or sale of latices to paper industry with progressive established chemical company. Send complete résumé including expected salary, education, and experience. All replies will be kept confidential. Send replies to *Tappi*, P483-55, 155 East 44th St., New York 17, N. Y.

CHEMICAL ENGINEER
OR
PULP AND PAPER GRADUATE

A vacancy exists in the Technical Department of our organization for a young, creative, aggressive chemical engineer or recent graduate of one of the recognized pulp and paper schools. Initial work will consist of technical investigations of various plant operations with objectives of increased production, improved process control and better paper quality. The opportunity is available to perform interesting work with modern, new plant equipment and be associated with new process developments.

Applicants must be recent graduates of a recognized college or university. Previous experience in pulp bleaching or pulping desirable. Essential qualifications are 2 to 5 years experience in the paper industry, initiative, self confidence, and ability to work with a minimum of supervision.

The opportunity for advancement in a modern, medium sized, one plant company of enviable location is excellent.

Applications will be treated with strict confidence. Send detailed resume of experience and education to—

TECHNICAL DIRECTOR
FINCH, PRUYN & COMPANY, INC.
GLENS FALLS, NEW YORK

PEROXIDE BLEACHING

Record of the Pulp Purification Session—40th Annual Meeting

FEBRUARY 22, 1955

The meeting reconvened at 2:10 p.m., Chairman Rapson presiding.

CHAIRMAN RAPSON: This is the second half of the sessions of the Pulp Purification Committee. This morning we had a fairly thorough discussion of the chlorine dioxide bleaching, and this afternoon we are going to have a discussion of peroxide bleaching and its various applications.

Now, as chairman of the Pulp Purification Committee, I am merely starting off the proceedings this afternoon. The Peroxide Symposium was organized by Bob McEwen, the secretary of our committee, and he has done an excellent job in its organization. I know full well how much effort, how much time and trouble, go into the organizing of a session like this since I had to do the one for this morning, and I want to express my appreciation to Bob for the effort he has put into organizing this session.

I am also asking him to take over the chairmanship of this session and so I shall now turn it over to him. Bob McEwen!

(ROBERT L. MCEWEN (Becco Chem, Div., Food Machinery & Chem. Corp.) assumed the chair.)

CHAIRMAN MCEWEN: Members of TAPPI: We are very glad to see the size of the group gathered, and hope that more will join us in the next few minutes.

After talking it over, we feel that the presentation of the papers and the panel discussion to follow would be smoother were we first to present the papers, and have you hold your questions for later presentation to the panel.

On the program today are three papers, and following the presentation of the papers there will be a panel discussion on which the authors, as well as three other gentlemen from the peroxide suppliers, will sit. We hope that you will ask them plenty of questions.

The first paper on this afternoon's program will be presented by John M. McEwen, technical director of the Weyerhaeuser Timber Co. mill at Everett, Wash., on the subject of "Commercial Application of Peroxides in the Bleaching of West Coast Kraft Pulps." Mr. McEwen!

Commercial Application of Peroxides in the Bleaching of West Coast Kraft Pulps

J. M. McEWEN, A. E. ERICKSON, and C. S. WALSETH

THE wood species used in the kraft pulping operations of the Weyerhaeuser Timber Co. is predominantly Douglas-fir. The pulping units are closely integrated with the lumber and plywood manufacturing facilities and the tree farm and logging operations. Roughly 75% of the Northwest timber stands is Douglas-fir and the remainder is a mixture of western hemlock, true firs, and red cedar. The former is the major source of raw material for lumber and plywood operations and the western hemlock and true firs are used in the previously established sulphite pulp mills. In our company, the western hemlock and white fir are used as a steady source of raw material for two bleached sulphite plants, whereas the pulpwood for the kraft operations is over 90% Douglas-fir with the remaining fraction comprising hemlock and cedar. In these integrated operations, kraft mill chips are produced from sawmill and plywood leftovers along with whole logs from thinning and relogging programs in the tree farms. In addition to the two bleached sulphite units, the company operates two bleached kraft units producing market pulp, a bleached kraft unit producing container board, and an unbleached kraft unit for liner board.

J. M. MCEWEN, Technical Director, Weyerhaeuser Timber Co., Everett, Wash.; A. E. ERICKSON, Technical Director and C. S. WALSETH, Research Supervisor, Weyerhaeuser Timber Co., Longview, Wash.

Of the various commercially used pulpwood species, Douglas-fir has certain unique and inherent chemical and physical characteristics. It has a relatively long fiber length and there are pronounced differences in fiber width and wall thickness between springwood and summerwood fibers. Under conventional kraft pulping techniques, the fiber is relatively high in alpha-cellulose and low in hemicellulose. These features are interrelated with the exceptionally high tearing strength, high bulk, and lack of gelatinization on beating. It has only moderate bursting strength, fold, and tensile development in comparison with northeastern United States and Scandinavian fibers.

The wood is cooked in conventional stationary digesters of about 10 tons capacity. Cooking is accomplished with circulation and indirect heating. The pulp is cooked to a standard permanganate number of 23, using an active alkali to moisture-free wood ratio of about 17%. A typical schedule calls for 2 hrs. to a maximum temperature of 173°C. with 1 hr. and 15 min. at temperature. The pulp is washed on three-stage countercurrent washers, screened and thickened on deckers or a fourth washer.

Three different kraft bleach plants are in use based on the following general sequence pattern: direct chlorination-wash, caustic neutralization-wash, high density hypo bleach-wash, high density caustic extraction-wash, and high density hypochlorite-wash. The first plant built in 1947 had all batch cells with dump chests to permit continuous washer operation. This plant used low consistency caustic neutralization and also has a sixth stage using hypochlorite in addition to the above. The second bleach plant uses all continuous towers with low consistency in the first two stages. The third bleach plant is a continuous tower system up to the final hypochlorite stage. This batch stage has eight Wolf-Fletcher-type cells. In this plant the first caustic stage can be operated at either high or low consistency. In addition, this plant has an additional final acid soak tank and washer.

After bleaching, the fibers are passed through Lindblad screens, followed by centrifugal cleaners ahead of the pulp drying machines. The pulp machines have fourdrinier wet ends, three presses, and Minton vacuum driers. The pulp is normally dried to 100% air dry (10% moisture on a moisture-free basis).

Table I lists the more salient bleaching conditions, typical chemical dosages, and pulp features after the various stages when only conventional bleaching chemicals are employed.

The bleaching process can be considered as a continuation of the primary digestion process in the sense that deligni-

Table I. Conventional Bleaching Conditions before Use of Peroxide

Unbleached pulp: permanganate number—23 (bleachability—9.5% chlorine); 1% CED viscosity, cp.—450

Bleaching sequence	*Chemical, lb./ton*	*Consistency, %*	*Time, hr.*	*Temperature, °C.*
Chlorination	140	3	1	18
First caustic	60	16	1	70
First hypochlorite	35	16	1	34
Second caustic	20	16	1	60
Second hypochlorite	30	16	3.5	35

fication is continued and undesirable constituents extracted with the ultimate aim of producing a stable cellulose fiber of good color and strength features. From a material point of view, the bulk of the delignification and purification is performed in the initial three stages with a minimum degradation and loss of desirable properties. The latter stages produce the final brightening action under milder chemical conditions since the pulp becomes progressively more sensitive to cellulosic degradation. From economic and practical considerations it would appear that special and costly bleaching agents be applied in the latter stages of bleaching and purification.

LABORATORY STUDIES

Procedures

Laboratory Bleaching. Laboratory bleaches were performed with pulp quantities of 1 to 2 lb. All caustic extraction, hypochlorite, and peroxide stages were carried out at 12 to 16% consistency by the use of Hobart mixers. Peroxide bleaches were carried out in a jacketted, stainless steel container with temperature control provided by hot water in the jacket.

Brightness. Samples from laboratory bleaches were acidified with sulphurous acid and formed into thick sheets on a Büchner funnel. These were air dried and pressed to provide a smooth surface. Brightness values, obtained on a G.E. recording spectrophotometer are reported as reflectance at 458 mmu, referred to MgO. The reported mill brightness data were obtained on the standard G.E. reflection meter.

Brightness Stability. After determining the brightness of the air-dried pulp sheets, the sheets were heated 1 hr. at 105°C. in a circulating oven and the brightness redetermined. The loss in brightness resulting from this accelerated aging treatment has been commonly used as an index of brightness stability. For convenience, the values for air-dried and oven heated samples are referred to as air-dry and oven-dry brightness, respectively.

Viscosity. Cupriethylenediamine viscosity was determined according to TAPPI Standard T 230 sm-50, using the falling ball modification. Values are reported as centipoises for a 1% solution.

Physical Testing. Pulp samples were formed into air-dried sheets prior to testing. Refining was carried out in a Vally beater with handsheets formed according to TAPPI Standard T 205 m-53, using vacuum couching. Handsheets were conditioned and tested at 73°F and 50% R.H. Strength factors are reported on the following basis:

$$\text{Bursting strength, \%} = \frac{\text{points}}{\text{basis weight}} (100)$$

$$\text{Tear factor} = \frac{\text{grains/sheet}}{\text{basis weight}}$$

The basis weight is determined as moisture-free lb./24 × 36—480 ream.

Preliminary Studies

Much of our early laboratory work during 1951 and 1952 was concerned with orientation in the effects of basic peroxide bleaching variables such as the quantities of peroxide, sodium silicate, alkalinity, temperature, and time. Consistency was confined to the range of 12 to 16% in order to stay within the practical operating limits of the high density bleaching facilities of our mills. In the early studies the application in the caustic extraction (fourth) stage showed consistent brightness gains of 1 to 2 points in the brightness range above 85. Although brightness gains were also obtained in final (sixth) stage applications, close comparisons were not made at that time and attention was centered on the fourth stage, since this presented the simplest point of addition for initial mill trials.

The effects of some of the variables as well as the extent of brightness gains in fourth stage peroxide bleaching are illustrated in Tables II and III. The presence of sodium silicate stabilizes the peroxide and an increase in silicate quantity slows down the consumption or decomposition of the peroxide. This is indicated in Table II by the peroxide residual remaining after the bleaching time of 1 hr. The final brightness was substantially unaffected by the variation in silicate quantity. Likewise, a decrease in alkalinity slows down the consump-

Table II. Effect of Silicate Quantity in Fourth Stage Peroxide Bleach[a]

	Caustic extraction	*Peroxide*		
4th Stage[b]				
Chemical added, lb./ton				
Na_2O_2	0	12	12	12
Sodium silicate	0	0	20	100
NaOH	40	28	28	28
Residual peroxide, %	...	0	15	25
Viscosity, 1% CED, cp.	71.4	79.6	77.3	77.2
5th Stage—hypochlorite[c]				
Chlorine added, lb./ton	15	15	15	15
Excess chlorine, lb./ton	7	7	9	5
Final pH	9.8	9.1	10.0	8.7
Viscosity	51	51	54	55
Brightness (air-dry)	85.2	87.4	87.3	87.6
Strength at 550 S.-R. freeness				
Burst, pt./100 lb.	173	177	177	172
Tear factor	2.25	2.25	2.15	2.20

[a] Based on mill third stage pulp: viscosity—156, brightness 69.6.
[b] Constant conditions: 65°C., 14% consistency, 1 hr.
[c] Constant conditions: 35°C., 16% consistency, 3 hr.

Table III. Effect of Alkalinity in Fourth Stage Peroxide Bleach[a]

	Caustic extraction	*Peroxide*			
4th Stage[b]					
Chemical added, lb./ton					
NaOH	25	15	10	5	0
Na_2O_2	0	10	10	10	10
Silicate	0	30	30	30	30
Residual Na_2O_2, %	...	0	Trace	6	32
Final pH	...	11.4	11.0	10.4	9.7
Viscosity	82	86	88	88	92
Brightness (air-dry)	69.5	79.6	78.4	80.1	79.1
5th Stage—hypochlorite[c]					
Chlorine added, lb./ton	15	...	15	15	15
Excess chlorine, lb./ton	6	...	6	6	7
Final pH	8.8	...	9.5	9.0	8.9
Viscosity (air-dry)	57	...	58	62	63
Brightness	85.5	...	86.2	86.8	86.8

[a] Based on mill third stage pulp: viscosity—106, brightness—70.2.
[b] Constant conditions: 75°C., 13% consistency, 1½ hr.
[c] Constant conditions: 32°C., 16% consistency, 3½ hr.

tion of peroxide, as shown by the peroxide residuals for bleaches listed in Table III. Considering particularly the fourth and fifth stage brightness data, there is no indication that the results were appreciably affected by the amount of alkalinity and the final peroxide residual.

The bleaches in Table II show a brightness gain of about 2.0 points with the use of 12 lb. per ton of sodium peroxide, in comparison with a control bleach with no peroxide. In Table III a gain of about 1.3 points with 10 lb. per ton of sodium peroxide is indicated. Viscosity and strength values for peroxide bleaches were substantially the same as for control bleaches. On the basis of consistent laboratory results, of which the data in Tables II and III are typical, mill trials with peroxide in the caustic stage were undertaken.

In the laboratory work, as indicated above, and in later mill experience, the rate of peroxide consumption, or the residual remaining at the end of a bleach, has not been found to be a critical factor when peroxide is used in the caustic extraction stage. No disadvantage has been observed in complete exhaustion of the peroxide. In fact, it appears that complete exhaustion is consistent with maximum peroxide efficiency. However, when peroxide is used as a final stage bleach, it is necessary to carry a peroxide residual at the end of the bleaching time to prevent alkali reversion. When the peroxide is exhausted in a caustic stage treatment, this reversion probably occurs, but is overcome in the subsequent final hypochlorite stage.

Sixth Stage Peroxide Bleaching

During the time that the benefit of peroxide in the caustic extraction stage was being determined in mill operations, renewed attention was given in laboratory studies to the potentialities of peroxide as a final stage super bleach with particular emphasis on brightness stability. Reports in the literature have indicated improved stability for pulp bleached with peroxide in the last stage (*1, 2*). The use of acid wash prior to the last stage was also said to be beneficial (*3, 4*).

A series of bleaches was made to determine the degree of acidity required for an effective acid pretreatment. This study was based on a sample of pulp taken from a bleach plant fifth stage washer. Portions of this sample were adjusted to various pH levels with sulphuric acid at 3% consistency and 20°C. After a 10-min. soaking period, the pulp was drained and washed with a small quantity of distilled water. A peroxide bleach, using 20 lb. per ton of Na_2O at 16% consistency and 75°C. was then applied to each sample. The effect of the pH of acid pretreatment on the peroxide stability is illustrated by the curves of peroxide residual versus time in Fig. 1. The residual curves show that a continuous improvement in peroxide stability occurred as the acidity was increased to pH 2.5.

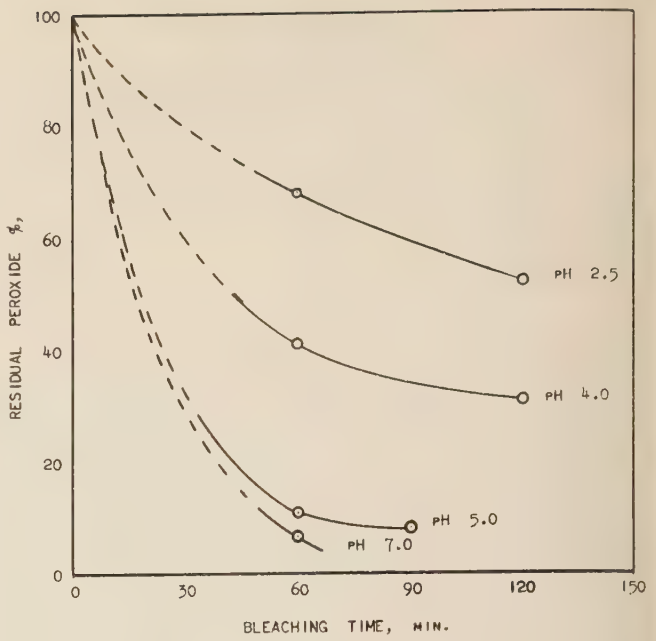


Fig. 1. Effect of pH of acid pretreatment on peroxide stability in subsequent bleaching stage

The series of bleaches listed in Table IV was made to compare six different fifth and sixth stage bleaching sequences as follows:

5th Stage calcium hypochlorite followed by
(1) 6th stage calcium hypochlorite
(2) 6th stage peroxide
(3) 6th stage peroxide with acid pretreatment

Table IV. Comparison of Peroxide and Hypochlorite in Sixth Stage Showing Effect of Acid Pretreatment and Effect of Calcium Versus Sodium Hypochlorite

	Calcium hypochlorite			*Sodium hypochlorite*		
5th Stage						
Chlorine, lb./ton		17			17	
Consistency, %		16			16	
Temperature		32			32	
Time, hr.:min.		3:00			3:00	
Final pH		9.0			9.0	
Residual Cl, lb./ton		7.5			9	
Acid wash	None	None	pH 2.5	None	None	pH 2.5
	$Ca(OCl)_2$	Na_2O_2	Na_2O_2	$NaOCl$	Na_2O_2	Na_2O_2
6th Stage						
Chemical, lb./ton	13	20	20	13	20	20
Consistency, %	16	16	16	16	16	16
Temperature, °C.	32	75	75	32	75	75
Time, hr.:min.	3:00	0:45	2:00	4:00	0:30	2:20
Final pH	8.9	11	11	9.1	11	11
Residual chemical	9 lb./ton	3%	27%	8.5 lb./ton	7%	42%
Pulp Properties						
Brightness (air-dry)						
5th stage	←	85.1	→	←	84.5	→
6th stage	88.4	88.2	89.8	87.0	87.8	89.3
Brightness (moisture-free)						
6th stage	81.4	83.4	85.3	81.5	82.5	85.6
Viscosity						
5th stage	←	78	→	←	80	→
6th stage	54	54	56	54	65	63

5th Stage sodium hypochlorite followed by
(4) 6th stage sodium hypochlorite
(5) 6th stage peroxide
(6) 6th stage peroxide with acid pretreatment

In the peroxide stages, 1% Na_2O_2 (20 lb. per ton) was used. This dosage is higher than has normally been found necessary, but was used to assure maximum brightness gains under the conditions used. The brightness results of these bleaches are shown graphically in Fig. 2. The results for equivalent bleaches based on calcium and sodium hypochlorite are compared by adjacent bars.

Figure 2 shows that peroxide alone gave substantially no improvement in air-dry brightness over the sixth stage hypochlorite, although the heat stability was improved somewhat. With the addition of an acid wash prior to the peroxide stage, however, a substantial gain in brightness resulted. The heat stability, or difference between air-dry and moisture-free brightness, was substantially the same with or without the acid pretreatment. The effectiveness of the acid pretreatment was substantially the same whether sodium hypochlorite or calcium hypochlorite was used in the fifth stage.

Consideration of Peroxide as Final Stage of a Five-Stage Sequence

A sixth stage peroxide super bleach was readily adaptable to our six-stage bleach plant by the conversion of the final hypochlorite stage. Our five-stage bleach plants did not present this possibility since there is only one hypochlorite stage following the second caustic stage. However, it would be possible to reverse the flow of stock to the last two stages to give the following sequence: chlorination, caustic extraction, hypochlorite, hypochlorite, and peroxide.

A series of bleaches was set up to test this possibility, and also to check the effect of an acid pretreatment in this sequence.

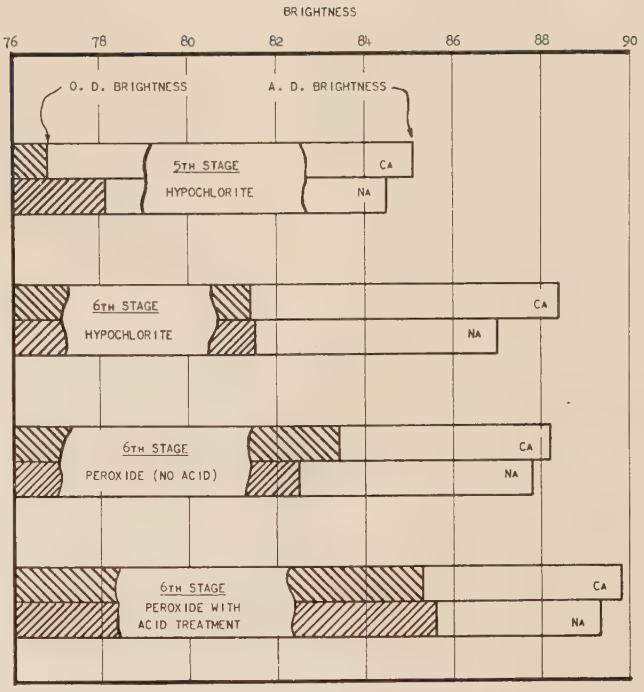


Fig. 2. Comparison of brightness and heat stability obtained in Sixth stage with hypochlorite and peroxide, following a hypochlorite fifth stage. Equivalent results based on use of calcium and sodium hypochlorite are shown by adjacent bars

Data on these bleaches are shown in Table V. It is shown that no benefit was derived from the reversed sequence with peroxide in the last stage. Furthermore, the results were not improved by the use of an acid pretreatment with either sequence. All bleaches with peroxide in a five-stage sequence

Table V. Effect of Point of Addition of Peroxide in Five-Stage Sequence

Bleach	*A*	*B*	*C*	*D*	*E*
		4th Stage			
	Caustic Extraction	Peroxide		Hypochlorite	
Acid pretreatment	..	None	pH 2.5		
Na_2O_2, lb./ton	..	10	10	Chlorine, lb./ton	20	20
NaOH, lb./ton	25	10	10			
Temperature, °C.	65	75	75		30	30
Time, hr.:min.	1:00	1:15	1:15		3:00	2:45
Peroxide residual, %	..	10	10	Final pH	8.8	8.9
Viscosity	76	73	68		55	53
Brightness (air-dry)	76.0	82.3	83.1		84.5	84.8
		5th Stage				
	Hypochlorite			Peroxide		
				Acid pretreatment	None	pH 2.5
Chlorine, lb./ton	20	20	20	Na_2O_2, lb./ton	10	10
				NaOH, lb./ton	10	10
Temperature, °C.	30	30	30		75	75
Time, hr.:min.	3:10	3:00	2:50		1:15	1:15
Final pH	9.1	8.9	9.0	Peroxide residual, %	8	9
		Properties after 5th Stage				
Viscosity	49	40	35		38	38
Brightness (air-dry)	84.7	86.7	86.8		86.4	86.6
Brightness (moisture-free)	79.2	81.8	81.7		81.3	81.3
Burst, % (550 S.-R.)	162	160	164		153	152
Tear factor (550 S.-R.)	2.40	2.35	2.45		2.40	2.40
		6th Stage—Peroxide				
Conditions—same as bleach F (5th stage)						
Peroxide residual, %	16					
Viscosity	39					
Brightness (air-dry)	87.6					
Brightness (moisture-free)	84.0					
Burst, % (550 S.-R.)	155					
Tear factor (550 S.-R.)	2.45					

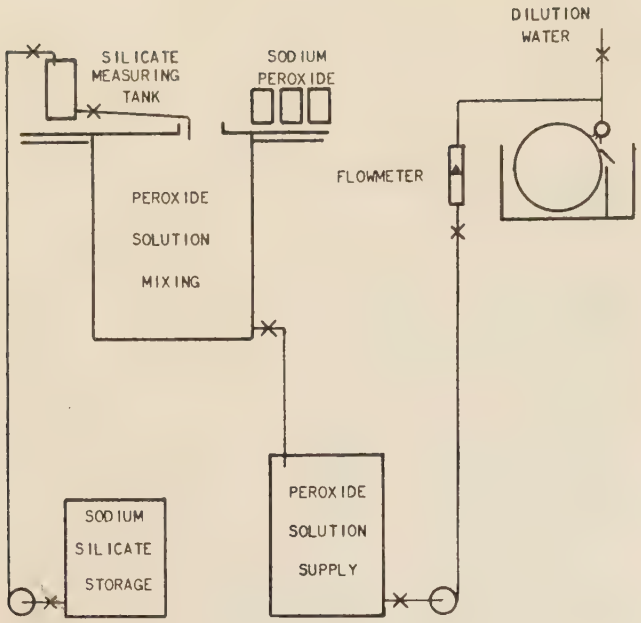


Fig. 3. Batch system for preparation and supply of sodium peroxide solutions

showed a substantial gain in brightness over a conventional five-stage sequence with no peroxide. When a sixth stage peroxide bleach was added to the conventional five-stage sequence, brightness and stability were definitely superior to results obtained with peroxide in a five-stage sequence. In this series of bleaches, the only difference between the five-stage and six-stage sequences with peroxide in the last stage is the lack of a second caustic extraction in the five-stage sequence. The difference in brightness and heat stability between these two sequences points up the fact that a final super bleach stage does not eliminate the necessity for careful preparation of the pulp in the early stages of the sequence.

The fact that the acid wash did not prove beneficial in this series of bleaches is probably related to the source of the pulp. The third-stage pulp used as the basis for this study was from a different mill than the pulp used in the prior experiments with acid pretreatment. This indicates that the acid wash ahead of a peroxide stage is a treatment which may or may not be beneficial, depending upon the source of the pulp, or the circumstances or conditions to which the pulp has been exposed. The opinion is commonly held that the improved peroxide stability obtained by an acid pretreatment is at least in part the result of removal of heavy metal ions from the pulp. If this is the case, the benefit of the acid treatment may logically depend upon the extent to which these ions are present in a given mill system.

EQUIPMENT REQUIRED FOR PEROXIDE BLEACHING

The equipment additions or changes required to provide for the use of peroxide in our kraft bleach plants were relatively simple and inexpensive. A schematic diagram of the system used to prepare and supply the bleaching chemical solution is shown in Fig. 3.

The systems originally provided on a trial basis have continued in use for over a year with only minor modifications or improvements. The system used in both mills consists of a mixing tank for peroxide solution, facilities for storage, supply, and measurement of sodium silicate, a storage or supply tank for the peroxide solution, and a supply pump and rotameter. The requirements of construction materials are not stringent.

With regard to the details of the system and procedure for preparation, storage, and supply of the peroxide solutions, information and advice from peroxide suppliers is readily available and has proved entirely satisfactory. There is no need to cover these details in this paper. However, it may be of interest to point out what was used for peroxide mixing facilities in our mills, as examples of the adaptability of existing equipment. In one bleach plant there were eight batch bleaching cells in the final hypochlorite stage. Ample capacity in this stage permitted one of these cells to be converted to use for mixing peroxide solution. This cell, which is tile lined, has a capacity of 13,500 gal. so that 2000 lb. of peroxide can be made up in a single batch at 16 grams per liter. The iron screw-type agitator in this type bleach cell provides adequate agitation and has not proved harmful to peroxide stability. A second cell has recently been converted to provide additional capacity for mixing and storing the peroxide solution. In another location, it was convenient to convert one of the calcium hypochlorite bleach liquor make-up cells to mix peroxide solution. This concrete tank has proved entirely satisfactory. In both cells, peroxide solution is mixed only once a day, requiring $1^1/_2$ to 2 man-hr.

The peroxide-silicate solution is applied to the pulp through a shower pipe as the stock leaves the washer. It is diluted with a flow of water immediately ahead of the shower for improved distribution. An independently metered caustic solution is used to provide controlled alkalinity. In one mill the stock is heated with steam in a double shaft mixer before dropping into a continuous high density tower. In the plant with batch operation, the steam is admitted directly to the Batch cell, and about 30 min. is required to bring the temperature up to maximum.

The second peroxide system to be installed was designed substantially as a permanent batch system. The cost of this system was $5000 which may be considered a low investment for the provision of a revised bleaching stage.

The use of a special bleaching agent such as peroxide is not the only important consideration in the production of high brightness, and maximum brightness stability. Of at least equal importance are such factors as water and white water quality, washing, careful preparation of the pulp in the initial purification stages, and neutralization of residual alkalinity after the final bleaching stage. The provision of facilities to allow proper attention to these factors must not be neglected if maximum pulp quality is to be obtained.

APPLICATION OF PEROXIDE IN CAUSTIC EXTRACTION STAGE

The mill in which peroxide is now regularly applied in the caustic extraction stage employs the following sequence: (1) chlorination; (2) caustic extraction, hot-high density; (3) hypochlorite; (4) caustic extraction—peroxide; (5) hypochlorite; (6) acid wash.

All stages are continuous except the second hypochlorite stage which employs batch cells. Each of the stages listed is followed by a washer. Calcium-base hypochlorite is used. The chlorination, caustic extraction, and hypochlorite stages are conventional operations.

The acid wash stage was incorporated in the bleach plant design to provide for the reduction of ash on dissolving pulp grades and to improve washing on regular grades. It is not properly considered a bleaching stage, though the thorough washing which it provides is a very important factor in the production of a high brightness, stable pulp. Only sufficient acid is applied to maintain a headbox pH of about 7.0 at the Minton drier.

This plant employs Lindblad screens after the bleach plant. These are high consistency (2%) screens and do not provide the effective dilution and washing action obtained with conventional flat screens and deckers. The acid wash stage compenstates for this factor.

Peroxide Stage Conditions

When converting to peroxide we only substituted peroxide

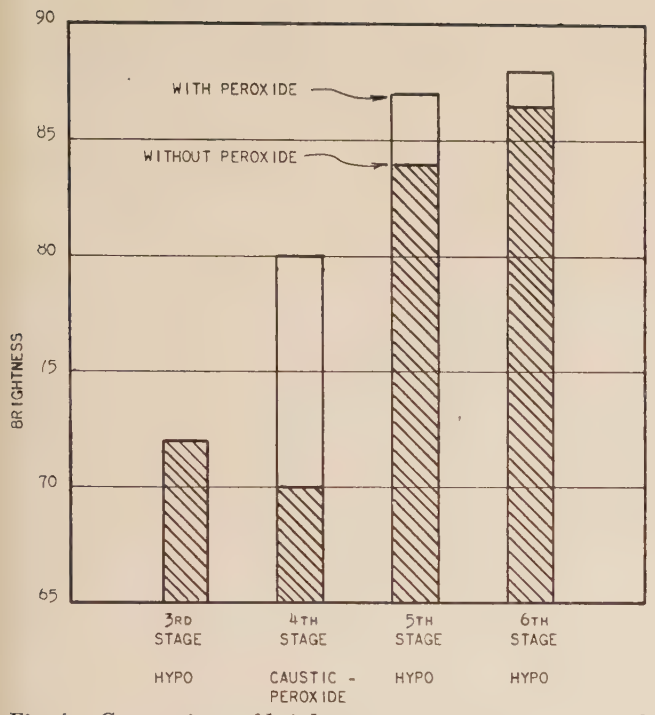


Fig. 4. Comparison of brightness at successive stages with and without peroxide in fourth stage

solution for part of the caustic, and increased the temperature. The normal conditions are:

Na_2O_2—7 to 13 lb./ton
NaOH—7 to 13 lb./ton (Na_2O_2 plus NaOH should total 20 lb./ton)
Consistency—16%
Temperature—75°C.
Time—1 hr.
Final pH—11
Final Na_2O_2—none

When peroxide is used in the caustic stage a substantial brightness gain is made in comparison with the brightness after a normal caustic extraction. This differential is narrowed down in the subsequent hypochlorite bleach. In the original peroxide mill trial a survey of conditions after each stage was made to compare with normal operation. The manner in which the brightness varied from stage to stage for the peroxide sequence as compared to the normal sequence is shown in Fig. 4.

The bleaching potential of peroxide can be directed toward either a maximum increase in brightness or toward higher strength. If higher strength is desired, the addition of peroxide is accompanied by reduction in hypochlorite stage conditions. During one trial period with the fourth stage peroxide bleach, conditions were set for the objective of maximum brightness for a week, then the final hypochlorite stage conditions were cut back for a period to give maximum strength at normal brightness. Average results for these periods, as compared with normal quality without peroxide are shown in Table VI.

Table VI. Results of Mill Trial with Peroxide in Second Caustic Stage of Five-Stage Bleach Plant[a]

Objective	*TAPPI brightness increase, pt.*	*Bursting strength increase, pt./100 lb.*	*Net cost increase, $/ton*
High brightness	1.5	5	2.10
High strength	0.5	25	1.82[b]

[a] Using 10.5 lb. Na_2O_2/ton.
[b] Taking credit for reduced hypochlorite dosage.

APPLICATION OF PEROXIDE IN FINAL STAGE

The results of laboratory investigations, previously mentioned, justified a mill trial with peroxide in the last stage. One of our bleach plants was well adapted to this, having two batch hypochlorite stages after the second caustic stage.

The sequence in this bleach plant is as follows: (1) chlorination; (2) caustic neutralization—cold, low density; (3) hypochlorite; (4) caustic extraction—hot, high density; (5) hypochlorite; (6) hypochlorite—peroxide.

All stages are batch except the second stage neutralization which is a low consistency, low temperature treatment. Each of the stages listed is followed by a washer. Residual alkalinity in the sixth stage stock is neutralized with sulphur dioxide ahead of the washer. The only change required to adapt the last hypochlorite stage in this sequence to peroxide was to provide for increased temperature. To accomplish this, direct steam was piped through a steam ring at the bottom of each batch bleaching cell. A rotameter and shower were provided for the addition of peroxide solution at the fifth stage washer.

The conditions which have been developed for sixth stage peroxide bleaching are:

Na_2O_2—8 to 12 lb./ton
NaOH—none
Consistency—16%
Maximum temperature—70°C.
Time—1½ hr.
Final pH—10.7
Final Na_2O_2—15 to 20% of initial

These conditions differ from the fourth stage application in that no caustic is used in addition to the sodium peroxide, the total time is slightly longer, and a substantial residual peroxide is carried to the end of the bleach. It has been found necessary to carry this residual in order to prevent alkali reversion. Early experience showed that when the residual dropped to zero, the brightness off the machine dropped about 2 to 3 points. There is evidence that 0.1% chlorine as hypochlorite added to the Bellmer in such an instance will correct the condition, bringing the brightness back to normal. The addition is made at the Bellmer because of the poor mixing that would result from addition to the bleaching cell. Occasion to verify this in the mill has been very limited but in one borderline case the results were good.

Acid Treatment

A short trial was made to determine the effect of an acid

Table VII. Comparison of Results with Peroxide in Fourth and Sixth Stages from Mill Trials in Six-Stage Bleach Plant

Type of peroxide bleach	*Na_2O_2 quantity, lb./ton*	*No. of stages*	*Brightness increase, pt.*	*Bursting strength increase, pt./100 lb.*	*Net cost increase, $/ton*
Fourth stage	10	6	1.3	0	2.00
Fourth stage	10	5[a]	0	15	1.40
Sixth stage	10	6	1.0 (+1.0)[b]	10	2.57
Sixth stage with acid pretreatment	7	6	1.0 (+1.0)[b]	10	2.13

[a] One hypochlorite stage eliminated.
[b] Recession in bale (1-month) reduced by 1.0 point.

wash prior to the peroxide stage. Sulphuric acid was added at the suction of the stock pump which delivers diluted stock to the fifth stage washer. The stock was acidified to pH 3.5 to 4.0, requiring 25 lb per ton of sulphuric acid.

The peroxide application was reduced 30% (from 10 to 7 lb. per ton) and the strength and brightness of the pulp remained at the normal level, as did the brightness recession. This trial was necessarily of short duration because the fifth stage washer and stock pump were not constructed of acid resistant materials. Results of this run suggest the possiblity of maintaining a higher brightness level with the normal peroxide application. This was not tried because of the equipment limitations. Following this run the peroxide dosage was left at 7 lb. per ton for a short time. A 0.5 to 1.0 point brightness drop resulted. In order to take advantage of the benefits of an acid pretreatment, replacement with acid resistant equipment where necessary is scheduled for this plant.

Comparison of Fourth and Sixth Stage Peroxide Bleaching

It is of interest to compare the results which have been obtained with fourth stage and sixth stage peroxide bleaching in the same bleach plant. This comparison is shown in Table VII. The values shown in this table represent an appraisal of operating data and pulp quality for periods of extended operation. When peroxide was used in the fourth stage, followed by two hypochlorite stages, the brightness gain, compared to a bleach without peroxide was about 1.3 points, and pulp strength remained unchanged. When one of the final hypochlorite stages was cut out, the brightness gain was eliminated, but pulp strength increased as indicated by a gain in bursting strength of 15 pt. per 100 lb. at 550 S-R freeness. When the peroxide was used to replace the hypochlorite sixth stage the burst increase was 10 points and the brightness increase off the machine was 1.0 point. However, indications are that brightness reversion in the bale was reduced by 1.0, so that a net gain of 2.0 points was obtained. This comparison indicated a definite superiority for the sixth stage application in this mill.

IMPROVED CONTROL

The brightness gains which have been shown to result from the addition of a peroxide bleaching stage may appear to be small. However, it is well known that as the brightness level is increased in the range above 85, additional gains are obtained with increasing difficulty. Furthermore, when it is attempted to operate in this range with only the conventional chlorine, caustic, and hypochlorite stages, the control of bleach plant operation to maintain maximum strength and brightness is a delicate and touchy matter. One distinct advantage of the peroxide bleaching stage which we cannot measure in points of brightness and bursting strength is the the fact it has smoothed out the over-all bleach plant operations and minimized the problems of control.

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Chairman McEwen: Thank you very much, John McEwen, for presenting such an interesting and lucid paper.

The next paper is "Bleaching Northern Kraft with Peroxides," by R. E. Noreus and R. P. Hella, of Northwest Paper Co., and the paper will be presented today by R. E. Noreus.

Bleaching Northern Kraft with Peroxides

R. E. NOREUS and R. P. HELLA

The results reported in this paper were obtained in the commercial operation of sodium and hydrogen peroxide bleaching stages at The Northwest Paper Co., Cloquet, Minn., during the past year. The pulps were produced from jack pine for use in their own paper mills.

A TAPPI monograph (*1*) on pulp bleaching was published in 1953. Peroxides in the bleaching of kraft were indicated to be in the mill trial stage and not yet in production processes. Later reports (*2–5*) on this subject were published during 1954 on laboratory and development work. There appears to be very little published information on commercial peroxide operations. It is in this category that the following observations are reported.

In general, it can be said at the beginning that the use of sodium peroxide in commercial kraft bleaching over an 8-month period in a chlorine, peroxide, hypochlorite process has produced a brighter, stronger pulp in four stages than was formerly obtained in five stages with a chlorine, caustic, hypochlorite process. Superbleaching with hydrogen peroxide in wet laps has increased the brightness additionally on small tonnages when desired.

SODIUM PEROXIDE BLEACHING

The bleach plant from which these data have been obtained started operation in 1948. It is a continuous five-stage tower system designed for 100 tons air-dry, unbleached basis, jack pine kraft pulp. The five-stage sequence consists of the following: first, low density acid chlorination; second, Hooker chlorination in which low density acid chlorination is followed by a neutralization with lime; third, medium density caustic extraction; fourth, medium density hypochlorite; fifth, low density hypochlorite.

In converting to sodium peroxide, the third stage caustic extraction was chosen as the most desirable location for peroxide addition. The only additional equipment required was that necessary to make up and deliver the sodium peroxide bleaching solution to the tower mixer. This solution replaced the caustic solution formerly used.

It was determined shortly after changing over to the sodium peroxide system that the desired 3 points of brightness—from the 78 to 79 range to 81 to 82—could be obtained with the fourth stage by-passed. Since it was a medium density stage, it fitted into a three-stage sulfite bleach process. This made possible the discontinuance of a high cost third stage batch bleaching on sulphite pulp with a resulting lower cost sulphite bleaching.

The peroxide bleached kraft reported here then consisted of four stages: first, acid chlorination; second, Hooker chlorination; third, sodium peroxide; fourth, calcium hypochlorite.

Bleaching conditions for stages three, four and five of the two systems were as follows:

Standard System

Stage 3—Caustic Extraction:
- 1.25% NaOH on air-dry pulp
- 11% consistency air-dry
- 150°F.

Stage 4—Hypochlorite:
- 0.4% chlorine (calcium hypochlorite) on air-dry pulp
- 13% consistency air-dry
- 100°F.

Stage 5—Hypochlorite:
- 0.4% chlorine (calcium hypochlorite) on air-dry pulp
- 3.5% consistency air-dry
- 100°F.

R. E. Noreus, Manager, Technical Service Department, and R. P. Hella, Manager, Pulp Manufacturing Department, The Northwest Paper Co., Cloquet, Minn.

PEROXIDE SYSTEM

Stage 3—Sodium Peroxide:
0.8% sodium peroxide
2.0% sodium silicate (42° Bé.)
0.12% Epsom salts
11% consistency air-dry
160°F.

Stage 4—Hypochlorite:
0.4% chlorine (calcium hypochlorite) on air-dry pulp

Comparative Results

A summary of the mill data has been compiled in order to compare the results obtained from bleaching with the standard five-stage system and the peroxide four-stage system. These data are taken from the months of March–October inclusive 1953 for the five-stage standard system, and March–October inclusive 1954 for the four-stage peroxide system. During these periods, bleaching conditions in the three stages used for both systems were unchanged.

From this point on, the original five-stage system will be referred to as "standard" and the four-stage system as "peroxide."

The unbleached pulp had an average permanganate number of 22.1 in the standard pulp and 20.6 in the peroxide pulp.

Standard pulp was bleached at an average of 117 air-dry tons per day unbleached basis compared to 124 for peroxide pulp. This increase in production rate together with the elimination of one stage reduced the total bleaching time from 400 min. for standard pulp to 260 min. for peroxide pulp. Hypochlorite bleaching time was reduced from 204 min. in the two stages for standard pulp to 78 min. in the one stage on peroxide pulp.

Over the comparison period, the peroxide system produced an 81 average pulp brightness compared to 79 with the standard system. More recently, by obtaining consistencies over 4% in the low density stages, 82 to 83 brightness has been maintained regularly. The over-all gain, therefore, now appears to be 3 to 4 points. Papers made from the peroxide pulps are increased in brightness equivalent to the pulp increase.

A comparison of the relative strength drop on bleaching for the two processes has been made. These data were taken from approximately 3000 bleached tests and 1000 unbleached tests for each time period. Pulps were beaten in a 3-lb. laboratory beater to 760 ml. Schopper-Riegler freeness. For comparison, the unbeaten freeness was approximately 840 ml. The data reported were taken on 37 lb. basis weight, 24 × 36—480, hot, moisture-free test sheets. Under these conditions, the decrease in bursting strength results by bleaching was 2% for the standard pulp and only 1% for the peroxide pulp. The decrease in Elmendorf tear resulting from bleaching was 10% for the standard pulp and only 9% for the peroxide. While the difference was slight, the advantage for both tests was with the peroxide pulp.

Using the drop in brightness on heating pulp sheets at 105°C. for 1 hr. as a measure of brightness stability, the results on mill pulp were inconsistent but indicated that both pulps had approximately the same range, 6 to 9 points. With the same test applied to laboratory bleached pulps, the advantage, if any, appeared to be with the standard pulp.

Some data were available on white 100% bleached kraft papers made from the two types of pulp. After approximately 11 months of natural aging under identical storage conditions, the paper from standard pulp had decreased 0.3 to 0.4 points less in brightness than the paper from peroxide pulp, indicating very little difference in this property.

Based on 1954 chemical costs, the four-stage peroxide pulp had an additional cost per bleached air-dry ton of $2.44 when compared to the five-stage standard pulp.

Using mill bookkeeping calculations, the shrinkage in weight through bleaching was 0.6% less for the peroxide pulp.

Conclusions

From the mill results obtained up to this point, the substitution of a sodium peroxide stage for the final caustic extraction stage has produced a very satisfactory pulp. The brightness of both the pulp and the resulting paper has been increased with no loss in strength and with fewer stages required. In this particular operation, the additional chemical cost of $2.44 per ton was partially met by using the idle stage in another pulp bleaching sequence with a resulting cost saving to the bleach plant in labor, maintenance, and power.

SUPERBLEACHING

While kraft brightness in the 81 to 82 range meets most of the paper mill requirements, there are occasional demands for small tonnages in the 84 to 85 range. This pulp has been supplied by using the Becco cold steep process (*4*).

Bleaching Conditions

In this process, bleached kraft from the bleach plant is showered with a hydrogen peroxide solution as the sheet passes through a wet machine. The impregnated laps are stored at room temperature. Brightness increases to approximately 85 after a period of several days and then gradually decreases.

The rate of application of chemical on the air-dry pulp has been 0.4% of 50% hydrogen peroxide, 2.5% sodium silicate (42° Bé.), and 5 lb. of Epsom salts per 1000 gallons of bleach solution. The liquid flows by gravity from either of two makeup tanks through a meter to a perforated shower pipe. The wet machines used are single press felt machines. The shower applies the bleach solution to the cut sheet on the felt just before the breaker roll. The air-dry consistency of the sheet is reduced from 37 to 30% by the bleach solution. Production rate per machine is approximately 40 tons per day air-dry.

The chemical cost of this process based on approximately 700 tons produced has been $2.66 per ton of air-dry bleached pulp.

Results

Over a period of 40 days lap storage, steep bleached pulp starting at 81 brightness increases to a peak of approximately 85 and then gradually decreases to 82 to 83 Under the same conditions, peroxide four-stage pulp starting at 81 gradually drops to 77 to 78.

In a limited number of strength tests made in the same manner as mentioned previously, there appeared to be no appreciable change in the bursting strength and tear of the steep bleached pulp after a 2-week storage.

Based on the 1-hr. heating of pulp sheets at 105°C., there is no significant difference in brightness stability between sodium peroxide bleached pulp and the steep bleached pulp made from it.

The use of steep bleached pulp in papermaking has been mainly confined to mixed pulp furnishes under conditions which have not permitted comparative results to be obtained.

Conclusions

Up to this time, it can be reported that hydrogen peroxide bleaching of bleached kraft after a sequence containing a sodium peroxide stage produces a pulp 3 to 4 points brighter with no strength changes and no change in brightness stability as measured by the 1-hr. heating test at 105°C. Chemical cost of the process has been $2.66 per air-dry ton. The effect of the additional pulp brightness on paper brightness has not been definitely determined.

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Chairman McEwen: We are very appreciative of Bob Noreus' presenting his paper. Again, I might mention that we will hold questions until the panel meets following the presentation of the next paper, which is "Pilot Plant Studies of the Hypochlorite-Peroxide Bleaching of Sulphite Pulp," by W. K. Voss and I. C. MacGugan. It will be presented by W. K. Voss, of the Ontario Paper Co.

Pilot Plant Studies of the Hypochlorite-Peroxide Bleaching of Sulphite Pulps

W. K. VOSS and I. C. MacGUGAN

The Ontario Paper Co. which operates mills at Thorold, Ont., and through its subsidiary, the Quebec North Shore Paper Co., at Baie Comeau, Que., is primarily a producer of newsprint for its publisher-owners. Surplus pulp production at both mills is utilized to make well-known sales pulps which are exported under the trade name "Opco Strong Unbleached Sulphite," "Hy-Bulk Groundwood," etc.

It had been noted by technical members of the Ontario Paper Co. that two Wisconsin mills were successfully employing a high-density bleaching method using hydrogen peroxide in a single stage—one on groundwood pulp and one on deinked waster directory paper. Accordingly the BECCO Chemical Div., who developed the peroxide method of high density bleaching, were approached to see if the method could be adapted to sulphite bleaching.

Laboratory bleaching trials were undertaken in the summer of 1953. These trials showed that pretreatement with hypochlorite bleach liquor is required for the low-cost bleaching of sulphite with peroxide at high density. Further tests were made at this time, including the effect of varying the alkali concentrations of the peroxide bleach liquor, pulp shrinkage, and viscosity tests. The latter indicated no fiber degradation took place during bleaching. Bleached pulps of 80+ brightness were obtained, and the chemical consumption from a cost viewpoint looked very encouraging.

Meanwhile arrangements had been completed with the University of Florida to carry out cooperative pilot plant bleaching studies in the Department of Chemical Engineering wherein Jackson and Church Co. had set up commercial equipment for high density bleaching. Four tons of 50% air-dry unbleached sulphite sheets from a Kamyr machine were baled and shipped for pilot scale bleaches in November, 1953, using bleaching conditions developed by BECCO. Samples of all bleached pulps were pressed, wrapped in Pliofilm, and returned to the authors' respective laboratories.

PRELIMINARY LABORATORY WORK

Since the decision had been made to conduct the trials on northern spruce sulphite pulp, it was felt imperative that prior laboratory evaluations be made to determine optimum formulas, bleaching conditions, and typical bleach responses expected from sulphite pulps of varying bleachability. High density peroxide stages were studied in view of previous studies comparing moderate versus high density systems, wherein high density showed chemical cost advantages of about 20% (*1*).

Representative samples of spruce sulphite pulp were selected from commercial cooks made at Ontario Paper Co. with varying permanganate numbers as follows:

Pulp	*$KMnO_4$ No.*	*Unbleached brightness*
E	13.5	61.7
F	16.9	58.3
G	18.9	62.4
H	15.0	63.0

Laboratory evaluations are summarized in Table I which shows only a few of the numerous tests actually made.

In these tests all pretreatments were made at 3.0% oven dry consistency and ambient temperatures. The peroxide stages were conducted at 25% moisture free consistency and at 50°C. for the noted retention periods.

As pulps E and H, of 13.5 and 15.0 $KMnO_4$ no., out of the four samples submitted, showed the most interesting results from a commercial viewpoint, only data from their evaluations have been shown in this table.

Table I

	Pretreatment	*Peroxide stage* —% *Applied chemicals*—			*Brightness* —*after*—	
Pulp	*% av. Cl_2 (as $Ca(OCl)_2$)*	*H_2O_2 (50%)*	*Silicate*	*NaOH*	*3 hr.*	*4 hr.*
E	3.0	1.00	4.00	0.75	81.5	81.4
	3.0	1.00	4.00	1.00	82.4	83.2
	3.0	1.50	4.00	1.00	79.5	81.8
	4.0	1.00	4.00	0.75	81.3	81.0
	4.0	1.25	4.00	0.75	82.7	82.2
	4.0	1.50	4.00	1.00	82.9	82.9
	Unbleached	...	...	...	61.7	...
H	3.0	1.50	4.50	1.25	79.2	80.5
	4.0	1.00	4.50	0.75	76.6	79.7
	4.0	1.50	4.50	1.25	82.4	83.0
	Unbleached	...	...	...	63.0	...

Since pulps E and H proved to be of particular interest, bleached yield determinations were made on these two pulps and the data subjected to statistical analysis which showed no significant difference between the yields on the two pulps. Average percentage loss for the two pulps was calculated at approximately 4.4% ± 1.6 at the 5% error level.

For the purposes of comparison, conventional two-stage chlorination-hypochlorite bleaches were given to pulp E which had a chlorine demand of 6.72%.

Chlorination: 4.7% chlorine, pH 2.0, 3.0% consistency, 45 min.
Hypochlorite: 2.0% available chlorine (as calcium hypochlorite), pH 10.0, 12.0% consistency, 110° F., 90 min.

The resulting brightness achieved was 74.0 G.E.

These data when contrasted to the bleaching results obtained by the hypochlorite–hydrogen peroxide sequence clearly showed the superiority of the latter method insofar as the bleach response of these particular sulphite pulps was concerned.

While the laboratory evaluation of the two-stage hypochlorite–hydrogen peroxide process showed quite favorable brightness levels it was felt that superior results would be achieved in pilot or commercial practice. This opinion was based on past experience which has shown that the more intimate blending of bleaching chemicals and pulp obtained by commercial high density mixing equipment could not be duplicated by laboratory techniques. Commercial equip-

W. K. Voss, Assistant to the Manager of Manufacturing, The Ontario Paper Co., Ltd., Thorold, Ont., and I. C. MacGugan, BECCO Chemical Div., Food Machinery & Chemical Corp., Buffalo, N. Y.

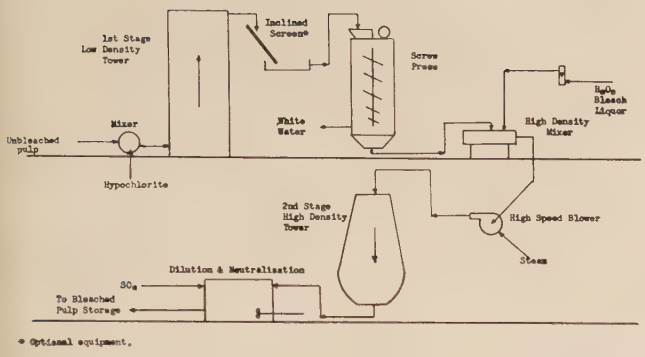

Fig. 1. Schematic flow plan of hypochlorite-peroxide bleaching process

ment invariably results in additional brightness increments of 3 to 5 points. Later experimental work using the pilot high density bleaching unit confirmed this surmise.

PILOT PLANT STUDIES

Since the pilot plant equipment for high density bleaching studies at the Engineering and Industrial Experimental Station of the University of Florida has been well described in previous technical papers (*2*) only a brief description will be given here in conjunction with the schematic flow sheet shown in Fig. 1. The pilot plant equipment consists of a steel tank for slush pulp storage, a small hydrapulper, a screw press, a refiner-mixer, a tile-lined retention tower, a neutralization chest, and the necessary piping and pumps.

For each trial run approximately 500 lb. of the selected sulphite pulp was slurried to 3.0% consistency in the hydrapulper and the predetermined amount of calcium hypochlorite (as HTH powder—70% available chlorine by weight) added. The pulp slurry pH was quickly adjusted to pH 9.0 with dilute sulphuric acid and pumped over to the storage tank. Reaction time was considered complete when more than 90% of the available chlorine added had been consumed by the pulp.

At the end of the retention time, the treated pulp was pumped to the screw press where it was dewatered to 38 to 45% moisture-free consistency. The white water from the press was sewered and the pressed pulp collected in drums.

The alkaline peroxide bleaching solution was metered to the rotary mixer. The bleach liquor strength is dependent on three conditions, namely; rate of pulp flow, minimum amount of solution necessary for optimum mixing of liquor and pulp, and the desired percentage of bleaching chemicals to be added to the pulp.

Pressed pulp and bleach liquor were then fed to the rotary mixer. From the mixer the treated pulp entered the high speed blower where it was mixed with steam and blown into the retention tower. Heated pulp was held in the tower for the specified retention time required for bleaching. Bleached pulp was then diluted in the base of the tower and pumped to a dilution and neutralization chest. Any residual peroxide remaining was neutralized in this chest with sulphur dioxide.

Table II

Pulp and run no.	1st Stage: Conditions	1st Stage: Brightness	1st Stage: Pressed consistency (moisture-free)	Formula moisture-free basis	2nd Stage: Bleach consistency	2nd Stage: H_2O_2 residual	2nd Stage: Retention, hr.	2nd Stage: Type bleach	Brightness: Fla.	Brightness: Becco	Brightness: Ont.
B I, K# 15.4	4.0% av. Cl_2	64.4	42.4	1.25% H_2O_2 (50%)	32.0	42.7	1	P	82.4		
	4.0% consistency			4.50% silicate		36.0	2	P	82.2		
	pH 9.0			1.00% NaOH	Temp.,	29.4	3	P	82.4		
	60 min. retention				133°F.	25.4	3	T	83.5	...	84.6
B II, K# 15.4	4.0% av. Cl_2	65.1	42.5	1.02% H_2O_2 (50%)	33.5	47.1	1	P	81.2		
	3.4% consistency			4.50% Silicate		37.0	2	P	82.4		
	pH 9.0			0.65% NaOH	Temp.,	34.6	3	P	81.9		
	60 min. retention				137°F.	23.1	4	P	80.9		
						...	3	T	82.8	86.2	85.7
A III, K# 13.6	3.0% av. Cl_2	65.2	43.5	0.495% H_2O_2 (50%)	35.0	13.4	1	P	80.4	83.0	83.7
	4.2% consistency			4.0% Silicate							
	pH 9.0			0.35% NaOH	Temp.,						
	80 min. retention				138°F.						
				0.74% H_2O_2 (50%)	35.0	24.6	1	P	81.5	...	...
				4.0% Silicate		20.2	2	P	83.3	...	85.4
				0.50% NaOH	Temp.,						
					138°F.						
				0.98% H_2O_2 (50%)	35.0	23.5	1	P	83.4	...	...
				4.00% Silicate		2.00	2	P	83.1	...	86.8
				0.75% NaOH	Temp.,						
					138°F.						
A IV, K# 13.6	None	...	50.0	1.24% H_2O_2 (50%)	36.5	38.2	2	P	72.9	...	...
				4.00% Silicate		27.6	3	P	74.5	...	...
				1.00% NaOH	Temp.,	22.2	4	P	73.7	78.0	78.7
					139°F.						
A V, K# 13.6	3.0% av. Cl_2	67.1	39.6	0.75% H_2O_2 (50%)	31.5	36.2	1	P	80.8	...	...
	3.6% consistency			4.0% Silicate		33.7	2	P	80.7	...	...
	pH 9.0			0.4% NaOH	Temp.,	26.9	3	P	81.7	...	...
	45 min. retention				138°F.	22.4	3.5	P	81.2	...	...
						20.0	3.5	T	80.5	...	84.0
B VI, K# 15.4	3.0% av. Cl_2	67.3	43.2	0.48% H_2O_2 (50%)	32.5	20.2	1	P	77.6	...	80.2
	4.2% consistency			4.0% Silicate							
	pH 9.0			0.35% NaOH	Temp.,						
	55 min. retention				143°F.						
				0.73% H_2O_2 (50%)	32.5	31.4	1	P	79.0	...	...
				4.0% Silicate		21.5	2	P	79.2	...	83.2
				0.5% NaOH	Temp.,						
					123°F.						
				1.0% H_2O_2 (50%)	32.5	35.3	1	P	79.9	...	...
				4.0% Silicate		32.0	2	P	81.4	...	84.2
				0.75% NaOH	Temp.,						
					124°F.						

Pulp A: Unbleached brightness 57.0 (U. of Fla.) 59.8 (Ont.).
Pulp B: Unbleached brightness 59.0 (U. of Fla.) 61.9 (Ont).

Table III. Bleached Pulp Properties

Sample identification (refer to Table II for description of stages)	G.E. brightness	Viscosity CED, cps.	Sizing[a] absorptiveness, g./sq. cm.	Heat aging[b] brightness	
				Start	Finish
Pulp A					
Run no. I—1st stage	64.4	23.6	...	...	...
Run no. I—2nd stage	84.6	25.5	...	...	...
Run no. III—1st stage	...	22.3	38.6	68.0	59.7
Run no. III—2nd stage	83.7	25.0	43.7	83.7	74.6
Run no. IV—single stage	78.7	27.9	37.3	78.7	70.2
Unbleached	59.8	32.1	135.1	60.0	53.7
Pulp B					
Run no. II—1st stage	65.1	23.2	...	...	...
Run no. II—2nd stage	84.7	25.3	40.4	86.2	77.7
Unbleached	61.9	35.8	...	...	...
Pulp A					
Two-stage chlorination–hypochlorite bleach	74.0	...	30.2	74.0	67.6

[a] Sizing test—TAPPI standard T 200 m-45.
[b] Heat aging—16 hr. at 110°C.

Pulp was then thickened and shipped to the authors' laboratories for testing.

The operating data and results from these trial runs are fully summarized in Table II.

It will be noted in Table II, that there are two types of bleached samples listed as P and T. Because of the large amount of pulp required to operate the high density retention tower for one test, it was found expedient to collect samples of treated pulp in 2-gal. pails as it entered the tower. These small samples (P) were then held at the noted temperatures in controlled temperature water baths and sampled for brightness and other control tests. By this method, several bleach runs using different formulations could be made in one day as contrasted to a single tower (T) bleach per day. During a tower bleach, pails of stock were also run as controls. Enough tower bleaches were made to demonstrate that a tower is the practical way of holding the pulp in retention during the bleaching process.

The bleached pulp samples, collected during the runs, were tested for G.E. brightness, viscosity, sizing, and heat aging. These results are given in Table III. Each of the 10 bleached pulps were tested for strength evaluations in the Valley beater, dirt counts, and optical properties. These results are summarized in Table IV.

One of the more important problems encountered in high density bleaching is the formation of tightly-packed bundles of fibers which are to be found throughout the pressed stock.

These bundles or knots are formed by the twisting-squeezing action of the screw press during the dewatering of the pulp. The rotary refiner-type chemical mixer acting on the high consistency stock breaks these knots into finer particles but does not eliminate them. The fine knots are present therefore during the bleaching cycle and have to be removed before the bleached pulp may be used.

Methods have been recommended for knot removal (*2*) which involve the use of additional equipment. While

Table IV. Physical Properties of Bleached Sulphite Pulp

Run no. (refer to Table II for bl. conditions)	Strength properties				Dirt				
	at 600 C.S.F.		at 300 C.S.F.		Specks per g.	Shive area per 10 g.	Shive no.	Papric count	
	Burst factor	Tear factor	Burst factor	Tear factor				L	S
B I	44.5	99	62.5	70	14	0	0	156	1192
B II	42.0	105	61.5	69	16	0	0	261	2344
A III a	41.5	90	54.5	62	14	0	0	141	1346
A III b	42.0	90	55.0	62	16	0	0	237	2328
A III c	41.0	94	55.0	64	20	0	0	132	892
A IV	30.5	95	54.5	64	25	0	0	168	2712
A V	34.5	109	54.5	66	14	0	0	582	3603
B VI a	44.5	90	61.0	62	20	0	0	231	2588
B VI b	45.5	81	61.5	66	17	0	0	212	1792
B VI c	45.5	95	63.0	62	18	0	0	131	1092
A unbleached	43.0	90	60.5	70	71	45	195	320	1880
B unbleached	52.0	98	63.0	75	75	50.5	225	220	1520

Optical Properties of Bleached Sulphite Pulp

Run no. (refer to Table II for bl. conditions)	Reflectance at 457 mmμ			Visual efficiency	Dominant wavelength	Saturation, %
	Av.	Max.	Min.			
B I	0.846	0.848	0.843	0.909	573	4.8
B II	0.857	0.854	0.855	0.917	573	4.7
A III a	0.837	0.838	0.835	0.908	573	5.4
A III b	0.854	0.857	0.852	0.920	574	4.9
A III c	0.868	0.871	0.865	0.928	573	4.4
A IV	0.787	0.789	0.785	0.874	576	7.0
A V	0.840	0.843	0.838	0.908	574	6.9
B VI a	0.802	0.806	0.798	0.890	574	6.9
B VI b	0.832	0.836	0.828	0.907	574	5.8
B VI c	0.842	0.846	0.839	0.914	573	5.5
A unbleached	0.598	0.602	0.593	0.694	579	10.2
B unbleached	0.619	0.623	0.615	0.706	579	9.3

additional equipment may be required in the case of some pulp types, it is believed, from the tests performed on the particular sulphite pulps bleached in this study, that normal agitation found in mill pumping and jordaning would be sufficient to deknot any nodules.

These tests also indicated that, in some cases, the center of the knot may contain some semibleached fibers. The brightness difference was small, however, and felt to have little or no effect on over-all brightness results. All brightness determinations on the final bleached pulps were made on pads prepared by agitating knot-containing bleached pulp.

ECONOMICS

On a comparable basis the cost of this system of bleaching and the costs of a conventional two-stage chlorine-hypochlorite system would look somewhat as follows.

Economics of Two-Stage 100-Ton Systems

	High-density hypochlorite-peroxide bleaching method	*Moderate density chlorine-hypochlorite bleaching method*
Equipment costs	$350,000	$505,000
Total capital investment, including building and connecting existing services	$600,000	$755,000
Yearly depreciation at 10%	$ 60,000	$ 75,500
Operating costs per air-dry ton		
1. Depreciation	$1.95	$2.45
2. Shrinkage	3.60 (4%)	7.20 (8%)
3. Chemicals	6.82	4.95
4. Labor	0.75	0.75
5. Steam	0.30	1.25
6. Power	0.25	0.25
7. Maintenance	0.50	0.50
8. Overhead, including supervision, research, and technical control	2.50	3.00
Estimated total bleaching cost per air-dry ton	$16.67	$20.35

CONCLUSIONS

1. These trials indicate that by the employment of the two-stage hypochlorite–hydrogen peroxide bleaching process, considerable cost savings may be effected as compared to the use of the conventional moderate density chlorination-hypochlorite technique. Brightness levels in the 80 to 82 G.E. range may be obtained by this process for a total over-all cost of $0.83 per point brightness per air-dry ton.

2. Initial capital investment is lower using the high density hypochlorite–hydrogen peroxide process. Maintenance and steam would be reduced correspondingly.

3. Final brightness levels obtained by this process are determined by the hydrogen peroxide concentration used in the second stage. On the pulps bleached on this project, brightness levels from 83+ to 86+ were obtained varying the hydrogen peroxide (50%) concentration from 0.5 to 1.0%. The higher brightness levels were obtained with no penalties in strength or yield loss.

4. While this study has been listed as a pilot plant scale investigation, it should be noted that the majority of the equipment used was of commercial size.

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Chairman McEwen: Thank you very much. We have planned a panel discussion which will be moderated by Ray Hatch, vice-president in charge of research and development for Hudson Pulp & Paper. On the panel will be our three speakers, John McEwen from Weyerhaeuser, Bob Noreus from Northwest, and Ken Voss from Ontario, together with Roy Fennell from du Pont, Fred Sheldon from BECCO, and Bill Schroeder from National Distillers.

To any of you who doesn't know Ray Hatch, our panel moderator, I'd like to introduce him and turn the meeting over to him at this time. He needs no formal introduction in view of his long service to TAPPI and to the industry.

Now, to start with we will take the three papers, and beginning with John McEwen, we will ask you to ask any questions that may have occurred to you during or after the reading of his paper on his particular subject.

(There were no questions.)

Well, then, how about Mr. Noreus' paper? Can we have some questions on that?

Mr. Painter (International Paper Co.): I want to ask Mr. Noreus whether he ended up his peroxide bleaching with a sulphur dioxide sour.

Mr. Noreus: No, sir.

Moderator Hatch: Any more questions? (There were none.)

Well, I guess that's going to wind that up, so I would like to have any questions connected with Mr. Voss' paper.

Edward K. Nissen (Solvay Process Div.): Maybe this would have been better for Mr. J. McEwen, but Mr. Voss mentioned the dirt count and the shives. They did some work on that, and I wondered if you noticed any difference in the shive count between the standard hypochlorite pulps and the chlorine hypochlorite.

Mr. Voss: I haven't any figures here, and the only chlorine hypochlorite bleaching we did was on a laboratory scale. Maybe Mr. Sheldon might remember what those tests were. I don't.

Mr. Sheldon: I don't.

J. M. McEwen: We did have some mill experience comparing peroxide with hypochlorite, and we didn't get a great difference. However, there seemed to be some gain in shives with hypochlorite bleaching. In other words, the more drastic hypochlorite removed shives, where the milder peroxide did not bleach them out so much.

Norman Lee: I would like to direct this question to Mr. Voss. Apart from the saving in capital outlay, do you know of any other advantages to this peroxide system that you talk about as compared to the conventional hypochlorite bleaching method?

Mr. Voss: Well, the bleaching cost, as estimated from these tests, is $3.68 per ton less, and I believe the brightness level is considerably higher, even taking that lower cost into consideration.

In other words, comparing these particular pulps, each point increase in brightness was obtained for 83 cents a ton up to the 80 and the 82 level, whereas from the tests made, the same increase in brightness would be around $1 per point, or a little higher with conventional hypochlorite bleaching.

Mr. Lee: Why did you use room temperature for the hypo stage? It seems rather surprising to me.

Mr. Voss: These formulas were worked out after many months of testing in the laboratory by BECCO. I'll have to ask them that question.

Mr. Sheldon: Actually, I don't think we had a great deal of data on various ranges of temperature in that stage. The pH of this hypochlorite is one of the factors in connection with that.

Mr. Voss: You notice, at the temperatures used, the hypochlorite was consumed in 60 min.—that is, up to 90% consumed in 60 min. in most cases.

Mr. Sheldon: If I understand that question, and I think I do now more than I did at first, you are speaking of the temperature of the hypochlorite in the second stage.

Mr. Lee: Yes.

Mr. Sheldon: Well, in that situation, a higher temperature drops the pH very rapidly. It increases the reaction, so that the pH drops into a range where there might be damage done to the pulp

Mr. Lee: Not with buffer, though.

Mr. Sheldon: It seems to work better if you do it at room temperature and without buffer.

Mr. Lee: I think maybe if you just cut down on the time there it might be better.

Mr. Sheldon: I think the danger of damage would be greater.

Moderator Hatch: Are there any further questions?

Mr. Nissen: I have a question I would like to clear up for myself. Mr. Voss indicates a difference of approximately $4 a ton between the peroxide and the hypochlorite bleaching. Is that correct?

Mr. Voss: Yes.

Mr. Nissen: That is to an equivalent brightness, is it not?

Mr. Voss: No. The brightness to be expected using the chemicals as outlined in the chlorine hypochlorite procedure, I think, would barely reach 80.

Mr. Nissen: Do you consider a new plant from your capitalization costs? And if I interpret that correctly—this being sulphite, of course—but if we go back to kraft, say, with the existing equipment, with the modifications necessary to use hydrogen peroxide, then it actually amounts to an increase in bleaching cost of about $2.44 a ton for an extra point or a point and a half brightness, if I have those figures correctly. Is that correct?

Mr. Voss: Is this kraft pulp bleaching that you are referring to?

Mr. Nissen: Yes, I am trying to get back into kraft.

Mr. J. M. McEwen: We had two different quotes here. One was $2.44, I think, and we found in our two operations it amounted to about $2 a ton. We can vary that, as I noted here on the board. We use 13 to 7 lb. per ton. Sometimes it bleaches hard, and we have to use more peroxide. When it is bleaching easy, we'll cut down, maybe, to 7 lb. a ton. Now, we are still in the process of development on this peroxide, and I have no doubt that as time goes on we'll be able to cut our costs. I might add one item on this cost proposition. That's one of the advantages of this acid pretreatment before peroxide. We have some indications that we can cut our peroxide usage by the use of a cheap acid pretreatment.

Moderator Hatch: Well, if there are no further questions on the subject of these papers, I have a series of questions here and I hope that the various members of the panel, or perhaps people from the floor, will be able to answer some of these, which are quite important as far as peroxide bleaching is concerned.

The first question is: Does the use of peroxide in the kraft bleaching process increase the potential capacity of a given bleach plant?

Mr. Schroeder: Bob Noreus stated they were actually able to eliminate a stage from their kraft bleaching process, and I think they were able to increase their output from 115 to 125 tons per day, and I think they sometimes run even higher than that.

In another mill claims have been made that they were able to increase their production by about 10%, and they also reduced their hypochlorite down to a very low percentage. They are saving on hypochlorite, so they have a stronger pulp with a better brightness.

A great many increases in production capacity would depend on the setup of the mill, of course, and every mill is a special problem.

Moderator Hatch: The next question is: "Can peroxides be used for bleaching all types of kraft pulp, such as hardwoods and softwoods from any area? What are differences relative to aging, brightness response, brightness level, and so forth?"

Mr. Fennell: The answer to the first question is that hardwoods have been bleached in the northern section of the country with good response and good results that are comparable to anything that we have done on other woods. The chemicals cost on hardwoods has probably been about 20% less than on softwoods.

Some bleaching has been done on hardwoods from the central part of the East, and the response is everything that we anticipated. I do not know of any hardwood bleaching in the western area.

To sum it up, we can say, that any of these kraft pulps respond in about the same fashion to peroxide bleaching.

Moderator Hatch: "What could be said about the use of hydrogen peroxide as a chemical superbleach on the pulp driers?"

Mr. Sheldon: A great deal. In general, everything that has been said about the bleaching of kraft with peroxide in the bleach plant *per se* applies to bleaching on the pulp drier with peroxide. Pulps from all parts of the country have been treated that way. There seems to be some difference in pulps. All pulps do not behave the same, and each individual mill and each individual pulp is a separate project.

However, excellent responses have been achieved on the pulp drier, and perhaps if we could have specific questions as to this operation, it would be helpful, but I will outline it a little bit first.

Peroxide is applied to the pulp right after the last wet press on almost any kind of a pulp-drying system, as hot air or cylinder driers, and bleached pulp is delivered at the layboy. The pulp has the major part of its brightness gain at the layboy, and has excellent brightness stability in the bale.

Moderator Hatch: Here's a question that has already been answered by John McEwen, but perhaps he might elaborate on it a little bit. "How does the brightness stability of bleached pulps compare, when peroxide is used in the second last stage and in the final stage? What are the merits of each use?"

Mr. J. M. McEwen: Well, of course, one of the big advantages of the use of peroxide in the next-to-final stage is that you have your equipment all set up to take a caustic solution, and you are adding an alkaline solution when you use sodium peroxide, so you do not have any engineering construction problems. As I indicated in my paper—we have some strong indications that you get a more stable pulp if you acid wash before a final peroxide treatment; in other words, as a final bleach with acid washing you get not only advantages as far as the brightness itself is concerned, but perhaps a point or so less brightness recession.

Moderator Hatch: The next question is, "What are the brightness stability characteristics of peroxide-bleached kraft pulp? Do they differ with different points of peroxide application?"

Mr. J. M. McEwen: There is a lot of mystery in this peroxide bleaching still. We still have the mystery of the two different plants, where acid washing gives it a definite help in the five-stage operation at one plant, yet the identical five-stage operation at the other plant, acid washing does not help.

I don't know for sure why this is. There is some difference in the processing. We have in one plant a continuous caustic stage, which is a low-density neutralization. In the other case, we have a full caustic extraction, a high temperature, high density caustic extraction, and it is possible that it is that caustic extraction. It is possible that that reacts the same as an acid wash. I don't know.

Mr. Fennell: To review a little of the background on the effect of this acid pretreatment: several years ago when we

first got into that we tried to explain it by the fact that manganese, copper, and iron are known catalysts for decomposing peroxide solutions. We analyzed several samples of lime from all over the country.

We know that lime varies from territory to territory, and from carload to carload, but we could not hang a story on that angle with our analyses.

There is evidence that the settling of the lime has something to do with it. That again would be tied into the fact that the metal hydroxides in a well-settled solution would be left behind, and some of the catalysts would not get into the pulp.

On the other hand, as I said, and as Mr. McEwen says, there is a lot of mystery to this thing. There are certain generalizations that we can make, and one is this, that the more lime that is used in the bleaching process, the more likely it is there will be problems associated with peroxide decomposition.

Secondly, it is generally observed that unsettled lime bleach has a greater adverse effect than settled lime bleach.

I think those are the two main things that we have found out so far. When soda bleach is used in commercial operation, in our own experience we have not found the need for using the acidification process; so to sum the thing up a little bit more, we can't say that lime is the specific problem, but we do know this, that we have a cure for it when we encounter it.

Therefore, wherever we attempt to install a peroxide process, we always evaluate the effect of acidification on a peroxide application. There is no mill running today where we have not made sure that we have the best process.

Mr. J. M. McEwen: I might back up that problem of lime settling a little bit, because, in fact, the mill that has no advantage on the acid wash does have a better lime hypochlorite settling system than does the mill that does have an advantage from using the acid wash.

Moderator Hatch: Here's a question that I would like to bring up, and I would like to hear some opinions from the audience, as well as from our panel. It is: "What is meant by brightness stability, and how is this important pulp property best determined?"

We have already had some answers on that because some of our panel who have given papers have given an idea of how they determine that brightness stability, or recession, and perhaps some of the audience can add something to what has already been said.

Mr. R. L. McEwen: I might just point out here that the Pulp Purification Committee of TAPPI is quite anxiously hoping to study this particular problem. We all realize that mills and laboratories of different types have so-called standard tests, for measuring brightness reversion—1 hr. at 105°C. and 2 hr. at 100°C. and 16 hr. at 100°C. in open containers, in closed containers, and relative humidity of thus and so, etc. There are many "standards."

It's quite a problem, and the committee, as well as the panel and everybody here, would be interested in any comments which would be of help to the Pulp Purification Committee.

Moderator Hatch: I would like to ask a question right now. How many in the audience, aside from the people that have already presented papers and commented on this thing, are actually using peroxide bleaching in one or more stages?

(Four people raised their hands.)

All right, now, here's the next question. This has been touched upon in the papers to some extent. "What has been the experience of the mills in regard to physical strength properties of bleached pulp with and without the use of peroxide?" By "physical strength properties" I mean bursting strength and tear and fold, tensile strength, any of the physical properties which we normally apply in determining degradation or destruction of physical qualities of the pulp.

I would like to hear from either members of the panel or members of the audience as to what they think about the use of peroxide as compared with conventional bleaching methods—and by that I mean chlorination, caustic extraction, and hypochlorite bleaching.

Mr. J. M. McEwen: Well, I might mention that in our case in order to obtain the brightnesses that we were shooting for of about 86 TAPPI brightness, we have to hit our pulp very hard with hypochlorite. By using peroxide, as the milder bleaching agent, we were able to cut back enough in our hypochlorite to partially pay for our peroxide, and give us much greater strength, and by that I mean all these properties that you are talking about.

Moderator Hatch: Well, can anyone say anything about certain of the chemical properties of the pulps as bleached with chlorine and hypochlorite, as compared with peroxide? Let's say the viscosity, too.

Mr. J. M. McEwen: We do have some specific information on viscosity control. We use viscosity as a control to help predict our strength. Our viscosity before we started peroxide bleaching was about 25 cp., and our control is now 40 cp. We have increased the viscosity that much in using the peroxide bleach.

Mr. Rapson: I think the question is perhaps not formulated quite right, Ray. As far as I am aware, if you heat pulp with peroxide at the right pH, there isn't any drop in viscosity, so the only change that can occur is that by using peroxide you use less hypochlorite, which is the thing that does the damage; is that correct?

Mr. J. M. McEwen: That's right.

Mr. Rapson: I would like to ask the question: "Is there any strength loss at all in peroxide treatment at the correct pH?"

Mr. Fennell: I think at the present time there are approximately 10 or 12 mills bleaching chemical pulps with peroxide. Eight of the 12—approximately eight of those 12—are using it in the caustic extraction stage. Two or three, perhaps, are using it as a final-stage bleach.

We in our work arbitrarily standardized our efforts on the use of this oven-dried test, where we subject the TAPPI handsheets to a temperature of 105° in an oven for 1 hr.

Now, a lot of erratic data have crept into this thing, because not all ovens are equipped with air circulation. If you do not have an air circulated oven, you might as well not carry out the test.

A good peroxide bleaching treatment will reduce the reversion characteristics of pulp by more than 50%, and by that I mean this: any hypochlorite bleach that we have encountered will revert 5 to 7 points, on the average, in the oven. Some are worse than that, depending on the stages that have been used, and the amount of degradation, but peroxide will reduce this 5 to 7 point loss down to 3 points, or a little less than that.

If the peroxide treatment is a sixth-stage bleach, we expect a reversion of $2^1/_2$ to 3 points, at the most.

When peroxide is used in a fourth stage, the oven stability will be about the same as when it is in a sixth-stage final treatment.

We have been able to reduce that last hypochlorite reversion down to about 4 points, and that is better than anything we have done in previous years. In other words, in a new, modern plant, operating under precise conditions, we have seen 86 pulp produced with only a 4-point drop, despite the fact that hypochlorite is used in the fifth stage.

This oven test correlates relatively with the papermaking qualities of that pulp. In other words, where a pulp is around 80 brightness, and, we'll say, reverted to 8 points in making paper, peroxide bleaching substituted for the last hypochlorite stage has reduced that drop somewhere around 50%.

We admit this is an arbitrary test, but having carried it out in about a total of a dozen mills we know now about what to expect as far as brightness stability goes. The same thing carries through whether you make the pulp and ship it, or whether you make it into paper. There have been advantages demonstrated both ways.

As I mentioned before, there are six mills that are operating every day with peroxide, and there are four to six others that operate intermittently. By that I mean they may use it only 3 days a month, or they may use it 1 or 2 weeks per month, but the results in every case have shown that as we put peroxide into the process and reduce the amount of hypochlorite used, the strength characteristics of the pulp have always gone upward. I can't recall a case where peroxide is used where we hurt the strength. We have always been able to improve it, and we improve it by the degree to which we have been able to take the hypochlorite out.

Mr. J. M. McEwen: We have skirted this business of color reversion several times, and your statement on the circulating oven to dry it brings to mind just how much correlation we have between this laboratory test and the actual reversion in the bale.

We are trying to obtain some data on that now, but we are not very far along. It has been our observation, for example, that if you take a sheet right off the machine and bale it while it is hot, you are going to get a significant amount of color reversion; but if you air cool it, wave it around in the air right away you don't get the color reversion. I am talking about the surface of the sheet in particular, because we find that often if you make a TAPPI handsheet out of that pulp you don't get nearly the amount of color reversion that you get on the surface of the sheet. It's a very small amount.

It is just the surface of that sheet which is being discolored, and particularly where you have it in the bale, where it is packed in tight with no aeration.

I just wonder about your technique of predicting reversion by the use of air circulation.

Mr. Fennell: Maybe I left the wrong impression on that. I am not attempting to say that there is any direct correlation between our oven test and what happens to the pulp at any given mill. We have found that this test is very good for one good reason. When we go into a mill to do a job, it enables us to get an answer within the hour, and we are on the way to the next job. We have found that this test is just as good as others for our purpose.

I know some people who put the pulp in an oven for 16 hr. at 120°, and they calculate an answer from that data. Perhaps their test is far better than ours, but I know that every time we have run this simple test we have been able to show an advantage, compared to hypochlorite, and those advantages will obtain whether your make paper or sell pulp.

The data this test has produced have shown far better brightness stability both in the bale and when it is received at a given plant. Therefore, while this test is arbitrary, it still is one of the best indicators that we can do to help sell peroxide.

Mr. Lee: I have a few questions to ask about color reversion. I think that to a large extent color reversion is somewhat dependent on washer efficiency. Has anyone here ever shown the relationship between washer efficiency, and has anyone here ever shown the relationship between Prelinger number and color reversion? I think that that might be an aid. I have never done it myself.

Mr. J. M. McEwen: Maybe there are a few characters in the crowd that don't know what this number is that you are talking about. Maybe you can explain yourself.

Mr. Lee: It's the organic number, the measure of the organic number.

Mr. Schroeder: Yesterday Mr. Giertz of Sweden was discussing that subject. Swedish Pulp Research men have done a lot of work on reversion in the past 10 years, and they found that when carbonyl groups were left in the pulp they were subject to reversion, but if they were oxidized to carboxyl, the color reversion was much less.

Now, is that the basis of your number, or does it have any relation to that?

Mr. Lee: It isn't the number to which I referred.

I have one other caution that I think you all ought to look out for when you are doing these color reversion tests. It all depends on whether you are running the brightness on the standard TAPPI sheet or on the pulp itself.

Take running brightness tests on the pulp itself. We have found that there are materials in that pulp that do affect the brightness considerably, but they are water soluble and can be washed out, and are washed out when you are making your standard brightness sheet, so that is something to watch in this work.

Mr. Schroeder: There is another factor that I have observed in several mills, on the hot baling of pulp off the machine. I think several mills have discovered that if they are able to cool the pulp, their brightness reversion is considerably less.

Mr. Lee: We tried that in experiment, and we did find a slight difference, yes.

Mr. Schroeder: And I think another factor is the use of the Minton vacuum drier, where you dry at a lower temperature. Vacuum drying decreases brightness reversion, as compared to drying in an open-drier section of the conventional kind.

Mr. J. M. McEwen: I don't know that anybody will back you up on this business of helping your color reversion by a good wash, but we'll certainly back you up 100% on that.

Moderator Hatch: I would like to bring up a little matter concerning optical properties. With the GE brightness tester, if the sheet is rough you can't get the same brightness reading as you can on a smooth sheet, for the simple reason that the optical system on the GE brightness tester doesn't give you the true spectral reflectivity that you can get with the GE spectrophotometer, for example.

That is something that we have found out in the past. I don't know whether it has been your experience or not.

Mr. J. M. McEwen: The fact is that at times we can raise the apparent brightness of the sheet from a point to a point and a half just by smoothing up the sheet.

Moderator Hatch: Now, there are always trends in the pulp and paper industry. Somebody starts something, and his neighbors find out about it, and they follow suit. The next question has reference, of course, to peroxide bleaching, but I think it is equally important in general, conventional bleaching, and that is, "What are the advantages of changing from calcium hypochlorite to sodium hypochlorite"—of course, bearing in mind that your sodium hypochlorite is more expensive. I would like to bring that question up.

Mr. Lee: Doesn't that depend on what kind of pulp you are making?

Mr. Sheldon: Generally, our experience has been that soda base hypo will give a better response, discounting the cost.

Moderator Hatch: Well, I know that the tendency nowadays among mill designers and designing engineers who are called in to put in a new bleach plant—their tendency is very definitely leading toward the use of sodium hypochlorite, and discarding calcium hypochlorite entirely. Of course, I think that is more true in kraft pulp than it is in sulphite pulp, because there is always the tendency of forming very hard-to-bleach compounds of coloring matter with the calcium when it is present, and the sodium hypochlorite seems to keep those colored products in solution, so that they are more efficiently bleached.

Mr. J. M. McEwen: I wonder if anybody here has had any experience in kraft pulp, switching over from calcium to sodium.

Mr. Lee: I think another reason, Ray, is that the sodium lends itself to automatic manufacturing, more so than the calcium.

Moderator Hatch: Well, that's true, and then you don't have the sludges to take care of, and there are always certain losses, of course, in separating the sludge with calcium hypochlorite. If you keep your alkalinity high enough when your liquor is made, there is no settling problem.

Most of the time we have been talking about kraft pulp, but I have a couple of questions here in connection with sulphite pulp. The first question is: "Can the same process be used on sulphite where the peroxide stage is at 12 to 15% density? If so, what are brightness results and comparative chemical costs, between the moderate and high-density systems?"

Mr. Sheldon: The two-stage hypochlorite-peroxide system can be used with a peroxide stage of moderate density. High density saves about 20% of the chemical. Depending on brightness level, high versus moderate density, the cost to get to 80 brightness would be $6 as against about $7.20; or at 85, about $8.50 as against $10.50.

Moderator Hatch: Most everyone knows that the peroxides have been very successful bleaching agents for groundwood. In fact, you can get more brightness gain with use of the peroxides than by any other method on groundwood.

Now, the question is posed: "What about the use of peroxide with semichemical?" There is more and more semichemical being produced in this country every day, and "What are the advantages of the peroxides for semichemical bleaching?"

Mr. Fennell: There aren't any commercial applications of peroxide in semichemicals in which we are involved. We have done some pilot work and our decision was something like this—that if you use chlorine, caustic, and hypo, and you want to make an improvement on that pulp, it seemed to us that the best way was to install a fourth stage and use a very small amount of peroxide. We were able to improve the color about 6 points, as far as brightness is concerned, but we weren't able to sell that process. As far as single-stage, we were never too successful, but we have been hoping that with the advent of Centri·Cleaners, some progress might be made.

We weren't able to do a very good job, because there was dirt that interfered. If we raised the brightness, the dirt was more prominent than at the 60 level, so we did not sell an application on that process. I know there is a tremendous interest in bleaching semichemical pulp, but where we are going to fit in the picture, I don't know. We are keeping our eye on it, at any rate.

Mr. Sheldon: Our work on semichemical has been pilot and laboratory, with studies similar to the two-stage hypochlorite-peroxide described by Mr. Voss. I would like to confirm Roy Fennell's observation, that we hope that we can get cleaner pulp to work with.

On pilot runs, 56 brightness semichemical pulp was bleached in two stages, hypochlorite and peroxide, to 81, with a yield saving over a straight hypochlorite system of 4 to 5%.

In this particular two-stage both steps were carried out at moderate density. Nine per cent available chlorine was used in the first step—considerably higher than on the sulphite—and 0.8% of peroxide; 50% H_2O_2 was used. Strengths were equivalent to two-stage hypochlorite bleaches, and the saving was about $3.25 per air-dried ton.

Moderator Hatch: Well, this about covers all the questions that have been handed in, and I would like to have some questions or discussion from the floor. We have covered quite a bit of territory as far as peroxide bleaching is concerned this afternoon, and there should be some questions that have arisen in your minds concerning some particular phase of the peroxide bleaching process.

Roscoe C. Masterman (International Paper Co.): We know that something was mentioned about the bleaching of groundwood with peroxide, and something was said about bleaching sulphite. I know that quite a few years back there was a little talk about bleaching groundwood-sulphite mixtures. What's the present trend on that?

Mr. Sheldon: We have always been of the opinion that it is better to bleach the two pulps separately, if possible. Bleaching a mixture can be done, and is being done, however.

Mr. Fennell: Bleaching a pulp separately does give a real opportunity to refine each individual stock to the extent that they prefer. On the other hand, I believe that there are advantages to mixing the pulp if the bulk of your product is going to require just one furnish.

People who have a diversified line of paper products will undoubtedly perfer to bleach pulps separately. However, I believe there have been some applications in the past where a single black plant was advantageous at the time, and I wouldn't be surprised if probably there will be more in the future. It certainly involves a detailed analysis of what products you are going to make, and also a calculation of what is involved in capital expenditure in case you plan to put in two bleach plants.

Moderator Hatch: Well, we had a very interesting discussion this morning on the use of chlorine dioxide as a bleaching agent, and we have had a very interesting discussion on the use of the peroxides as bleaching agents. I wonder if there is anyone in the audience who would like to, as a result of the two meetings, make any comments on the relative merits of both. (No one responded.)

Mr. Lee: Why don't you include calcium hypochlorite while you are at it? I am not convinced.

Moderator Hatch: Well, of course, we have certain things like oxidation potential that we can fall back on when we want to argue for one system or the other, but as a matter of fact it appears to me, as a result of attending these two meetings—I have been out of the bleaching game for quite a little while, but of course, I have read a lot of literature—and it seems to me that chlorine dioxide bleaching sort of got the jump on peroxide bleaching for the simple reason that those products were not so readily available until comparatively recently, and now that sodium and hydrogen peroxide are readily available, I look to see the peroxides advance in a considerable degree and become more truly competitive with chlorine dioxide bleaching.

I would like to say this, that while chlorine dioxide bleaching and the preparation of chlorine dioxide has been pretty well established, there is still quite a hazard with the use of chlorine dioxide which you don't have in the use of the peroxides. I don't know how much bearing that may have on individual mill decisions, but it seems to me that if we can obtain exactly the same results with sodium peroxide or hydrogen peroxide, as compared with chlorine dioxide, the initial investment, the corrosion problem, and a number of other things, would possibly give a slight edge to the use of the peroxides.

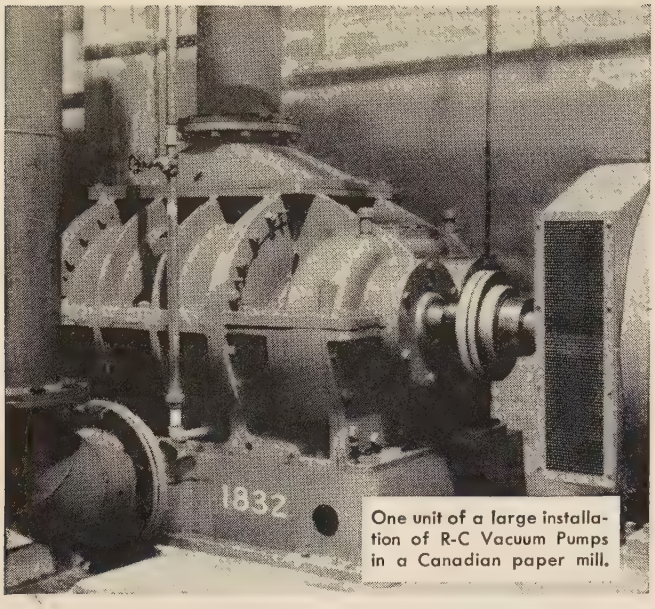
Perhaps some of these gentlemen who represent suppliers here—and there don't seem to be any of the chlorine dioxide people here right now, but maybe it would be a little bit illuminating if they would tell us something about the relative investment costs and setting up for the use of peroxide, as against setting up for chlorine dioxide.

Mr. Nissen: Perhaps it would be better if we had a little statement from du Pont or BECCO on the use of peroxide in the 90 brightness range. (Laughter.)

Mr. Sheldon: Rather than thinking in this particular instance of hydrogen peroxide as a replacement for chlorine dioxide, we are thinking of it as a supplement.

With chlorine dioxide bleached pulp coming off the drier, as I recall, about 88, we have used 0.2% H_2O_2 50% on the drier and have obtained 90 to 91 brightness.

Mr. Schroeder: Possibly I am a little prejudiced, but it



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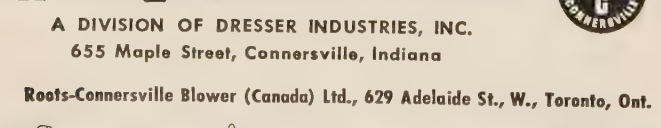

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seems to me that the mills consider the use of chlorine dioxide and peroxide in two different ways. With peroxide they want it to fit into their existing mill bleachery, as John says, so that it will cost them only $4000 or $5000 to convert. If they happen to have only low density stages for possible use, they are not interested.

On the other hand, if they are interested in using chlorine dioxide, they feel no compunction about investing $300,000 or $400,000 in a chlorine dioxide plant, with the stages so designed that they get the optimum advantage out of chlorine dioxide. No one seems to care to install a peroxide stage where the peroxide could operate at its best conditions also.

MR. NISSEN: I think that's a very excellent point. The cost of a chlorine dioxide plant without considering engineering contingencies will run about $110,000. I am not speaking of any particular process right now.

On the bleach plant equipment itself, you have to determine the difference between your bleach cell and tower cost using acid-resistant material, and material which would be satisfactory for peroxide bleaching.

MODERATOR HATCH: Well, as far as the equipment in the bleach plant itself is concerned, I think that a tower can be so designed that you can use either product without any serious corrosion difficulties. I think it is entirely possible to use either peroxide or chlorine dioxide as the final stage; so then it boils down to the investment in the two processes for preparing your oxidizing agent, and I think that you have been very honest in giving a statement on the cost of a chlorine dioxide generating plant. That is something that has to be taken into consideration by a mill that's making an investment.

MR. SHELDON: By way of contrast, the investment cost for installing a drier bleaching with peroxide—a complete system, including tank storage for H_2O_2, runs about $5000 to $7000.

MR. R. L. MCEWEN: Ray, I would like to ask the panel and the audience whether anyone would care to comment with regard to the values to be obtained in mill operation at the, let's say, 90 plus brightness level. In other words, can a using mill making paper from very high brightness pulp obtain an advantage with brightnesses in the 90 to 92 level, as compared with, let's say, 85 to 88?

MODERATOR HATCH: Well, Mr. McEwen has brought up an old question. How advantageous is it to make pulp at 90 brightness or 91 brightness, as compared with 86, 85, or 87 brightness?

Now, for many years I was connected with the pulp industry, and the reason why the pulp industry is always striving for higher brightness is because of competition. If they establish a brightness, say, of 87 or 88, then a competitor comes along and says, "Look at that pulp! Why, that's only 87 or 88 brightness. We can produce 90 brightness."

And so the mill has to strive for 90 brightness. It is purely a matter of competition. I don't think that for most purposes it is necessary to have these extremely high brightnesses. There may be certain definite reasons for it, perhaps in certain dissolving pulps or products of that nature, where brightness accompanies purification those high brightnesses are desirable, but for ordinary papermaking purposes I doubt that they are, and I think it is largely a matter of a battle between different pulp salesmen.

No one seems to want to comment on that. Well, if there are no further questions and no further discussion, I have about exhausted the number of questions that I could put to the members of the panel or to the audience, so I assume that you all have important dates and would like to get out of here, so, that being the case, I want to thank all the members of the panel for their excellent cooperation and the nice presentations which were made, and I hope that we will have occasion to discuss these major improvements in the bleaching process again at a later date, when more people have more experience. If there is nothing further, we will consider the meeting adjourned.

Progress in the Chemistry of Lignin—1943–1954

ELWIN E. HARRIS

In the 10-year period immediately before 1943 there were four discoveries that increased significantly our knowledge of the chemistry of lignin; these were, the isolation of a small amount of alcohol-soluble lignin directly from wood (*1*), the discovery of small amounts of several monomeric compounds related to lignin in the ethanolysis products of wood (*2*), the discovery that some isolated lignins and spruce wood gave high yields of vanillin when heated at 160° with nitrobenzene and alkali (*3*), and the discovery that hydrogenolysis of a methanol-HCl lignin gave high yields of compounds related to 2-methoxy-4-propyl phenol (*4*). A handicap at that time was the lack of information on compounds that may be considered as lignin model compounds.

Prior to this period there had been considerable difference of opinion among investigators as to aromatic nature of lignin. As a result of these discoveries and ultraviolet data on lignin and wood products, a polymeric aromatic structure for lignin composed of 2-methoxy-4-propyl phenol type building blocks was accepted by most investigators. These advances plus the need for a means of utilizing lignin have stimulated many investigators to do further lignin research. These researches have been aided by several reviews of the chemistry of lignin (*5–8*). In all these reviews the suggestion of Klason (*9*) that lignin is related to, if not made up of, polymers of coniferyl alcohol is acknowledged, although Klason himself had no experimental work to back up his belief. Coniferin, a glucoside of coniferyl alcohol, is present in the cambial sap of spruce and was considered as the source of lignin.

DISTRIBUTION AND NATURE OF LIGNIN

Several investigators have sought to gain further knowledge of the nature and distribution of lignin by studying plants other than wood. Suarez and co-workers (*10, 11*) studied the lignin in ferns and found its reaction similar to wood lignin. It could be freed from cellulose after hydrolysis by cupraammonium solution, dissolved by ethanol-hydrochloric acid mixtures, and the lignin reacted with sulphite solution at 125 to 135°. Vener (*12*) isolated lignin from a woodlike tropical fern. This lignin contained only 1% methoxyl. A lignin molecule having 49 carbons was found to have 2 carboxyl and 5 phenolic hydroxyl groups. This would indicate that a compound other than coniferyl alcohol was the precursor of this lignin. Lignin from grape epicarp and extracted grape seed (*13*) was low in methoxyl and contained pentosan. The yield of cupraammonium lignin was 35 to 37.9%.

Lignin was isolated from cork by De Baun and Nord (*14*). This lignin had a low methoxyl content. They found their lignin to be contaminated with extractives that would account in part for the low methoxyl values. Lignin in redwood bark is low in methoxyl and appears to be combined with the carbohydrate (*15*).

Some investigators (*16*) contend that lignin is a product of the isolation method and that lignin does not pre-exist in wood. Kratzl and co-workers (*17, 18*) reviewed the evidence for such a view and carried out experimental work to establish proof for the presence of aromatic compounds in wood. They point out that carbohydrates do not give vanillin and other aldehydes when oxidized by nitrobenzene and alkali and that aromatic compounds such as coniferyl alcohol and related compounds do. Only aromatic C_6C_3 type compounds give propyl cyclohexanol derivatives on hydrogenolysis and phenyl propane compounds on ethanolysis. Botanical methods, including optical observations, stains, and fluorescence, showed that isolated lignin and wood sections showed the presence of similar type aromatic compounds. Ultraviolet and infrared absorptions showed the presence of aromatic compounds in both isolated lignin and in wood sections. Color reactions to phenols and aromatic amines of isolated lignin and wood sections were the same. These authors conclude that these are proof of an aromatic lignin in wood.

In opposition, Schutz and Sarten (*19*) found that wood gave no coloration with diazo compounds and that the product isolated from spruce wood by the action of a diazobenzene 4-sulphonic acid gave no aromatic compounds related to lignin. They conclude lignin is a decomposition product. Piettre (*20*) extracted a product from wood that appeared to be related to humic acid. This was thought to represent the first stage of lignin formation. In support Lange (*21*) found evidence for one aromatic ring for each 10 carbons in lignin on the basis of ultraviolet absorption studies of wood and lignin. Some structural changes as shown by ultraviolet were found to have occurred in the isolation of lignin by the hydrochloric acid method, but no change was found in the amount of aromatic groups. Sections of wheat straw and several woods were treated with various chemicals and then with 1% NaOH (*22*). Photomicrographs of the sections showed dark areas where some delignification had occurred. Fractional extraction of wood with delignifying agents (*23*) was followed microscopically. A structural change occurred during lignin removal. Ploetz (*24*) found that pretreatment of wood with dilute acid permits removal of cellulose by dissolving in cupraammonium solution or xanthation solution.

A LIGNIN-CARBOHYDRATE BOND

Many of the chemical reactions of wood indicate the presence of some type of bond between lignin and carbohydrates in wood. On the other hand, some observations with the ultramicroscope on the microstructure of wood cast doubt on the possibility of a bond between lignin and carbohydrates in wood.

Further chemical experiments support evidence for a chemical bond. Supersonic vibrations (*25*) on lignocellulose at 300 kc. per sec. for 1 min. permit 55% of wood to dissolve in Schweitzer's reagent. The ultracentrifuge showed that 50% of that going into solution was alpha-cellulose. Colloidal grinding in the presence of hydrazine dissolved lignin not soluble otherwise (*26*). Swelling and staining experiments (*27*), optical observations in sodium light and between cross nicols, and x-ray data on jute fibers show that removing the last traces of lignin causes a great increase in the swelling of the fiber.

Wacek and Schroth (*28*) found alkaline nitrobenzene oxidation of the part of wood that dissolved with the hemicellulose when wood was extracted with 5% alkali gave vanillin, syringaldehyde, and the corresponding acid. The part of wood that remained in solution when lignin was isolated by the Halse method also gave vanillin, syringaldehyde, and the corresponding acids. They conclude that a lignin-carbohydrate compound was dissolved and not recovered.

Elwin E. Harris, Chemist, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.

If the failure to extract lignin from wood by organic solvents were due to a masking action of the cellulose, grinding of wood should increase the amount of lignin that could be extracted. F. E. Brauns and Seiler (*29*) treated sprucewood in a beater with water to produce colloidal wood but there was no increase in the solubility of lignin. They concluded the failure to extract lignin from wood was not due to mechanical reasons.

Grohn (*30*) contends that the procedure required for isolating lignin as well as the biosynthesis of lignin indicates a lignin-carbohydrate bond. Kawamura (*31–37*) and co-workers have isolated a lignin-xylose derivative by means of chromatography and have established that the xylose is bound to the lignin. This indicates that lignin is bonded to the hemicellulose of wood. Harris (*38*) found that treatments that hydrolyze ester or acetal linkages were necessary to bring about separation of lignin from carbohydrates. Soluble products produced by chlorination of wood in carbon tetrachloride and purified by water extraction (*39, 40*) yielded xylose, arabinose, and galactose on hydrolysis. Stewart (*41, 42*) removed a lignin-carbohydrate complex from wood by heating wood in methanol at 150°.

The solid phase produced by sulphonation of wood at pH 4 to 6 could not be resolved to lignin and cellulose (*43*). These researches lead to the conclusion that lignin is combined with the hemicellulose and possibly some of the cellulose. Some type of hydrolytic reaction is required to free the lignin.

LIGNIN ANALYSIS

Most analytical methods for lignin are based on the amount of residue remaining after hydrolysis. For accurate results all nonlignin extractives must be removed but none of the lignin. In the hydrolysis all carbohydrates must be converted to soluble products but no insoluble carbohydrate decomposition products formed. All lignin must be insoluble and the hydrolytic reaction should not cleave off parts of the lignin nor cause polymerization and loss of water, carbon dioxide, or other parts of the molecule. In no case are all these conditions met.

Several new procedures have been examined in an attempt to develop a more satisfactory analytical method. Chlorination, oxidation, or pulping reactions make some of the lignin soluble in the usual procedure. In order to overcome this, Giertz (*44*) determined the amount of lignin in pulp by dissolving the pulp in 76% H_2SO_4 and measuring the light extinction in a colorimeter. This procedure appears not to be satisfactory for wood (*45*). Plant material containing nitrogeneous materials must be given special treatment.

A method for making the lignin determination on fresh or wet plant tissue without preliminary drying was worked on by MacDougal and De Long (*46*). Jensen (*47*) used a preliminary treatment with 38% HCl to which was added concentrated sulphuric acid to cause hydrolysis. This mixture was then diluted and boiled. The effect of sulphuric acid concentrations of 64 to 80% on the yield of lignin from cereal straws was studied by Adams and Castagne (*48*). As was the case with maple wood (*49*), the minimum yield of lignin from straw with the maximum methoxyl was obtained with 72% H_2SO_4.

A titration method for lignin was developed by Seuzyu (*50*) in which lignin was chlorinated to make it soluble in sulphite solution. The lignin was then precipitated by an amine and the excess amine determined by titration. Ethylene-oxide lignin (*51*) plus the alkali-soluble lignin gave satisfactory lignin values. Kurschner and others (*52*) studied the possibility of determining the methanol produced by the action of 82% H_2SO_4 at 200°C. as a means of lignin analysis. A modified Tingle method was used for analysis of pulps (*53*) in which the pulp was dissolved in a mixture of concentrated hydrochloric acid and sulphuric acid diluted and then treated with sodium hypochlorite. The excess of hypochlorite was determined after 10 min. by adding potassium iodide and back-titrating with hypo. Keller and Borlew (*54*) studied the relation between chlorine number and lignin content of high-yield kraft pulps in an attempt to develop an analytical method. Thacker (*55*) attempted to develop a procedure for removing all extractives before hydrolysis with sulphuric acid.

Lignin from unextracted or partially extracted wood contains extractives or derivatives of extractives found in original wood (*56–59*). Some of these extractives are polymerized by acids and appear in the lignin residue.

Some lignin is removed by the solvents used for removing extractives from wood (*60, 61*) and by water extraction (*62–64*). This water-soluble lignin gives all the reactions of the insoluble lignin. Some lignin is soluble in the acid solution used for hydrolysis (*65*). Lignin that has been subjected to chemical treatment, such as chlorination in the preparation of holocellulose (*66–68*) or isolation by a method that puts lignin in solution (*69–72*), is more soluble in acid solution and does not give proper lignin values in the lignin determination.

ISOLATION OF LIGNIN

Soluble Lignins

Lignin isolated by the method of Brauns (*60*) has been examined for homogeneity. Hess (*73*) subjected spruce alcohol-soluble lignin to fractional precipitation from a dioxane solution into benzene. The molecular weight by osmotic pressure methods ranged from 2800 to 6700, the methoxyl content ranged from 14.1 to 15.7% and carbon content from 61.78 to 67.27%.

Chromatographic separation (*74*) of an alcohol-soluble lignin from blackwattle wood showed it to contain dark tanninlike compounds, a yellow fluorescent substance, and an almost-white lignin compound.

Nord and co-workers (*75–80*) found that the yield of alcohol-soluble lignin was increased if wood or other plant substances were subjected to the action of wood-destroying organisms, such as brown rot. This liberated lignin gave the same color reactions as wood lignin and yielded aromatic aldehydes when oxidized by nitrobenzene and alkali (*81*). Apenitis, Erdtman, and Leopold (*82*) found that brown rot acted to demethylate and depolymerize lignin.

Organo-sol-Lignin

Lignin is converted to an organo-soluble compound when treated with various organic solvents in the presence of a mineral acid or some catalyst.

Isolation of Lignin by Acetic Acid

Sprucewood was treated with acetic acid in the presence of magnesium chloride; 11.5 to 18% of the wood dissolved as a crude acetic acid lignin in three successive treatments (*83, 84*). The product contained 9.4 to 11.6 acetyl. When correction was made for the acetyl, the methoxyl content was 14.1 to 14.6%, hydroxyl content was 12.3%, and phenolic, 2.1%. Oxidation with nitrobenzene and alkali gave 10.9% vanillin as compared with 23% vanillin from cupraammonium lignin and about 27% from lignin in untreated wood. Pauly (*85*) prepared acetic-acid-lignin by heating sprucewood with acetic acid containing 0.3% H_2SO_4. The product was soluble in chloroform and acetic acid and had molecular weights of 898 and 1790.

Bell and Wright (*86, 87*) prepared acetic-acid-lignin from birch by heating birch wood with acetic acid. The water-insoluble product was 25 to 29% of the wood and contained 17.4% methoxyl. The chloroform-soluble fraction of the lignin contained about 21% methoxyl. Fisher (*88*) found the reaction of acetic acid with lignin in cornstalks to be aided by the presence of hydrogen chloride.

Isolation of Lignin by Methanol and Ethanol

A study of the isolation of lignin from wood by the use of

methanol or ethanol in the presence of hydrogen chloride has been continued. Schuerch (*89–91*) found that the amount of lignin extracted depended on the solubility of lignin in the extracting media. Addition of chloroform or dioxane increased the lignin extracted. Wacek and Hlava (*92*) found that lignin isolated by methanol or ethanol and hydrogen chloride had less carboxyl and less terminal methyl groups than lignin isolated by organic solvents, such as dioxane, acetone, or methyl ethyl ketone. Lignin was isolated from *Eucalyptus regnans* (*93*) by heating with methanol for 148 hr. and then with fresh methanol for 16 hr. The reaction was similar to a hydrolysis reaction. Fully methylated spruce wood when treated with methanol and hydrogen chloride (*94*) gave a methanol-lignin with 30.6% methoxyl.

An ethanol-lignin was isolated by Guillemonat and Traynard (*95*) and compared with a product obtained by extracting wood with cold ethanol. Analytical values did not agree. Hibbert and co-workers (*96*) carried out extensive work on the ethanolysis of wood with ethanol and hydrogen chloride with special study of the products that dissolved but were not precipitated by water. They found ethanolysis of maple wood and re-ethanolysis of ethanol-lignin gave the same low molecular weight depolymerization products (*97*) that were identified as 4-hydroxy-3-methoxy phenyl propanone and 4-hydroxy 3,5-dimethoxy phenyl-propanone derivatives (*98*). These products were synthesized and derivatives made (*99, 100*). Sprucewood gave only the 4-hydroxy-3-methoxy phenyl propanone and its derivatives (*101*). They conclude these products came from lignin progenitors (*102*). The products from maple wood represented 9.8% of the lignin (*103*).

Holmberg (*104*) did not find the propiovanillone products from spruce reported by Hibbert and co-workers but did find many sugar derivatives. The lignin remaining in the wood after ethanolysis reacted with thioglycolic acid in a manner similar to that in original wood. Gustafsson and co-workers (*105*) isolated an ethanolysis product from birchwood believed to be a dimer of syringyl glycerol.

Hagglund and Richtzenhain (*106*) subjected wood, various isolated lignins, and methylated lignins to ethanolysis. The yield of water-soluble oils was 10 to 13% from the various lignins except lignin isolated by a mixture of hydrochloric and phosphoric acids. Merewether (*107*) isolated 86% of the original lignin in *Eucalyptus regnans* by ethanolysis; it had a molecular weight of 1400 after purification and contained 2 ethoxy and 9 methoxy groups. Acid hydrolysis of this lignin removed ethoxy groups (*108*). Alkali lignin from *E. regnans* was ethylated by ethanolysis treatment giving a product with 24% alkoxyl calculated as methoxyl (*109*).

Lignin has been isolated from wood as an organo-sol-lignin by the use of many different organic substances. Sawdust of quebracho was extracted with ethyl-acetoacetate yielding 23.8% lignin with 16.01% methoxyl (*110*). Lignin was extracted from sprucewood by chloral hydrate yielding 22.4% of a chloral derivative (*111*). Acetonitrile, acetoxime, and acetamide extracted lignin from wood (*112*). Phenol and hydrochloric acid reacted with lignin to produce a soluble product in which ortho condensation to the phenol occurred (*113*). Thiophenol reacts in a similar manner (*114*). Freudenberg (*115*) showed that lignin could be extracted by dioxane and hydrogen chloride or tetrahydrofurane and hydrogen chloride from wood swollen by water. Lignin dissolves when wood chips are heated with triethylene glycol at 125° in the presence of aluminum chloride (*116*). Ethylene oxide (*117, 118*), in the presence of 5% H_2SO_4 reacts with wood lignin to form a soluble product. Ethylene glycol containing hydrogen chloride extracts lignin and leaves a cellulose pulp (*119*). The presence of water decreases the delignifying action (*120*). Gillet and Urlings (*121*) studied the delignifying action of three neutral solvents and found higher temperatures favor greater delignification. Nine consecutive cooks at 158° with a 1:1 mixture of butanol and water removed 92.6% of the original lignin from aspenwood (*122*).

Isolation of Lignin by Thioglycolic Acid

Holmberg and Gralen (*123*) produced a soluble lignin by treating wood with thioglycolic acid. They interpreted the reaction as being similar to the reaction of lignin with sodium bisulphite. Three treatments were required for delignification (*124*). Thioglycolic acid and hydrogen chloride extract a lignin from spruce with 12.6% methoxyl (*125*). Fully methylated glycol spruce lignin gives a derivative with 25.5% methoxyl. Thiohydracrylic acid appears to react more rapidly than the thioglycolic acid (*126, 127, 128*).

Isolation by Hydrogen Sulphide and Hydrosulphide

Hydrogen sulphide and sodium sulphide react with wood to produce a soluble lignin (*129*) with sulphur contents ranging from 4 to 17.5%. Water appears to be split off in the reaction (*130*). Some depolymerization occurs and distillable products are formed (*131*). The yield of thio-lignin is not increased by colloid milling of wood or by swelling agents (*132*). Monoethanolamine is a solubilizing agent (*133*). Previous methylation of wood almost completely inhibits formation of thio-lignin (*134*), which would indicate the reaction takes place through a hydroxy group (*135*). Some monomolecular degradation products are produced during the production of thio-lignin from aspen (*136*). Several derivatives (*137*) of thio-lignin from *Eucalyptus regnans* show its building blocks to contain 9 methoxyls, 1 sulphur, 1 enolic hydroxyl group, 1 phenolic group, 3 secondary, and 1 tertiary hydroxyls. Oxidation of the thio-lignin after methylation gives veratric, isohemipenic, and veratroylformic acids (*138*). Molecular weight fractionation shows thio-lignin to be a mixture of two main products, one with a molecular weight between 400 and 500 and another between 1000 and 1500. Carboxy groups increase with increase in time of cooking and with temperature; total hydroxyl and sulphur content are almost constant (*139*).

Isolation of Lignin by Alkali

Further study has been made of the isolation of lignin by palkali. Polya and Vallance (*140*) found that lignin precipitated from alkali pulping liquors and subjected to the usual sulphuric acid method for lignin determination yielded only 89% insoluble lignin with 14.5% methoxyl. Alkali lignin from *Eucalyptus regnans* (*141*) had an equivalent weight of 863 and contained 24.7% methoxyl. It contained phenolic and alcoholic hydroxyl groups and was acetylated, benzoylated, and methylated, showing the presence of 8 hydroxyl groups. The lignin could be separated into an ether-insoluble fraction and an ether-soluble fraction by precipitation from dioxane (*142*). A study of the lignin dissolved by alkali from beechwood at 100°C. showed that 35.5% was dissolved in 2 hr. by 8% NaOH as compared with only 15% by 4% NaOH in 48 hr. and 21.2% by 24% NaOH in 48 hr. (*143*).

Isolation of Lignin by Nitric Acid

A method has been developed for delignifying hardwoods by the use of dilute, spent nitric acid. Pulp yields were 38.8% of a high alpha pulp suitable for rayons and film (*144*). Many of the variables in nitric acid pulping were studied by Shinra and Tze (*145*), who also made a study of the lignin recovered from the process. Lieser and Schaack (*146*) nitrated sprucewood with a mixture of sulphuric and nitric acids. Nitro-lignin was dissolved from the nitration mixture by methanol. Removal of the methanol left a light brown residue with 10% nitrogen.

Hachihama (*147*) prepared a nitro-lignin by the action of 10% HNO_3 on rice straw for 30 min. at 50°C. The lignin was methylated, then oxidized to yield a product free from methoxyl groups. Traynard and Robert (*148, 149*) prepared

a nitro-lignin that they subjected to various treatments. They found the product had a molecular weight of about 1150, and contained 3 NO_2, 4 COOH 2 CO, 2 MeO, 2 phenolic OH groups. Reduction (*150*) with tin and hydrochloric acid gave no NH_2 groups. Freudenberg, Lautsch, and Piazolo (*151*) nitrated an acetylated hydrochloric acid spruce lignin with nitrogen pentoxide. The product contained 0.9 nitro groups per C_{10} and was insoluble in organic solvents and sodium bicarbonate. They conclude the product must be aromatic.

Isolation of Lignin by Sulphite Solutions

Considerable progress has been made in the chemistry of the sulphonation of lignin and in the chemistry of the product. Erdtman (*152*) found that the sulphonation of lignin was a two-stage process, one involved the sulphonation of the lignin without producing a soluble product and the other a hydrolysis-solubilizing step. At low pH both steps occurred simultaneously. At a pH of 4 to 6 only the sulphonation stage occurred giving about 65% yield of what Erdtman called a "low sulphonated lignin." Subsequent treatment with 0.3% HCL converted the solid to the soluble form. The low sulphonated lignin contained about 1 sulphur for 40 carbons or 4 methoxyls. About 33% of the lignin dissolved when sulphonated at pH 5.25 and had a ratio of 1 sulphur to 2 to 3 methoxyls (*153*). Further sulphonation of the insoluble lignin increased the ratio to 1 sulphur for 1 to 1.4 methoxyls (*154*, *155*). If the "low sulphonated lignin" is refluxed with ethanol, some ethylation occurs. Resulphonation at low acidity does not remove ethoxy groups, but at high acidity ethoxy groups are replaced by sulphonic acid groups (*156*).

Birch and a grass, when sulphonated at pH 4 to 7, react more slowly, indicating a lower content of sulphonatable groups (*157*). Lindgren concluded that two different types of linkages were involved in the two types of sulphonation. It is proposed that most of the sulphonation follows a reaction involving a benzyl-alcohol type hydroxyl at pH 6 to 7 and ether groups at lower pH levels (*158*). More work on the identity of these groupings has been done by Mikawa and co-workers (*159*, *160*) who used the reaction of lignin with hydrogen sulphide and phloroglucinol as a means of identifying the groups.

The kinetics of the first stage sulphonation were studied by Nokihara (*161*). The hydrolysis stage appears to be the rate-limiting reaction (*162*). If sulphonation of lignin occurs before hydrolysis, there is less damage to the cellulose (*163*) and lignin (*164*). Freudenberg, Lautsch, and Piazolo (*165*) found that high pH gave a lignin with 1 sulphur for 2 methoxyls. Further sulphonation does not increase the phenol hydroxyl, indicating an ether ring but not the furane ring may be split. Lange (*166*) examined wood, after various periods of cooking, under the microscope and by ultraviolet absorption. He concluded that sulphonation did not change the degree of unsaturation and that it was doubtful if a coumarane ring is cleaved by sulphonation.

Beechwood that had been prehydrolyzed, preferably by sulphur dioxide, was delignified by cooking with magnesium or sodium sulphite at pH 5 to 7 for 8 hr. (*167*). Alkali lignin was sulphonated at pH 8.8 (*168*), but the sulphonic group was split off again by heating with alkali at 160°C. Richter and Pancoast (*169*) in an extensive study have recently repeated a great deal of the experimental work on the sulphonation of lignin and delignification of several species of wood and have confirmed the various findings.

Properties of Lignosulphonic Acid. Lignosulphonic acid was precipitated from technical sulphite spent liquors by 4,4′-bisdimethyl amino diphenyl methane sulphate, brucine sulphate, and lead acetate (*170*). Recovery was poor but the products were similar, having about 1 sulphur for 2 methoxyl groups. Precipitated lignosulphonic acid was methylated by diazomethane (*171*). One methoxyl was introduced for each sulphite group, giving an ether-insoluble compound with 21.7% methoxyl and 7.85% sulphur and an ether-soluble compound with 23.1% methoxyl and 10.8% sulphur. Lignosulphonic acids were precipitated by fluosilicic acid, giving a product with 48 to 60% carbon and 14.8 to 16% methoxyl (*172*). Ligninsulphonate from fermented spent pulping liquor was converted to the ammonium salt by ammonium carbonate and then treated with ammonium thiocyanate and bromine or chlorine at 0 to 15° and then added to butyl alcohol to precipitate (*173*). The properties of the product indicate that thiocyanate had been substituted for a hydrogen in the aromatic ring.

Lignosulphonic acid precipitated from aspen pulping liquor contained 21% methoxyl (*174*). The methoxyl recovered represented 60% of the total in the wood. Attempts to prepare a sulphur-free product resulted in the loss of most of the methoxyl. Lignosulphonic acids from a "soft" commerical cook and from a "medium hard" laboratory cook (*175*) were compared by precipitation with benzacridine. The first to precipitate was lower in sulphur and gave a lower yield of vanillin on oxidation with nitrobenzene and alkali. Analysis showed that about 10% of the methoxyl in sprucewood was not a part of the lignin. Beta-lignin sulphonic acid (*176*) (the soluble lignosulphonic acid produced by cooking sprucewood at a high pH) has a higher sulphur content and gives higher yields of vanillin (33 to 38%) on nitrobenzene-alkali oxidation than the insoluble product.

Lignosulphonic acids having an apparent molecular weight of less than 2000 have been separated from spent commercial pulping liquors by dialysis (*177*) in 65 to 80% purity (*178*). Alkaline hydrolysis of the product caused an increase of 0.67 hydroxyl for each methoxyl group and also caused an increase in molecular weight.

An ammonium lignosulphonate was deionized and converted to a barium salt (*179*). This was precipitated in three fractions by adding acetone. The middle and last fractions were subjected to diffusion analysis. This product showed molecular weights from 1500 to 20,000 (*180*).

A barium salt of lignosulphonic acid that had been purified by dialysis was fractionally precipitated from water by ethanol. When these fractions were calculated on a sulphur and ash-free basis, composition was nearly uniform. Ultraviolet absorption spectra of the fractions was nearly uniform (*181*). Molecular weight determinations of lignosulphonic acid by Schwabe and Hasner (*182*) showed molecular weights ranging from 1865 to 6660 depending on concentration and purity. Using a shape factor of 4.6, Ivarsson (*183*) calculated a molecular weight of about 8000 for lignosulphonic acid. Resulphonation causes some lowering of molecular weight.

Melander (*184*) prepared sodium, potassium, and ammonium salts of lignosulphonic acid by mixing the calcium salt with the sulphates of the various salts, filtering off the calcium sulphate, and evaporating in the presence of sulphur dioxide. Methoxy derivatives of lignosulphonic acid were made with diazomethane and with dimethyl sulphate (*185*). Attempts to desulphonate lignosulphonic acid gave a product with lower methoxyl and hydroxyl content than alkali lignin from the same wood (*186*).

Isolation of Lignin by Hydrotropic Solvents

Heating of wood with about 10 times its weight of a concentrated solution of sodium xylene sulphonate causes lignin to dissolve (*187*). The solubility of the lignin increases as the concentration of the sulphonate increases above 20%. A 35% solution of the sulphonate yields a crude pulp in 48 to 50% yield in 5 to 6 hr. at 150° (*188*). Lignin is precipitated by diluting the recovered cooking liquor to 5% sulphonate. Advantage in yield and cost of chemicals over kraft pulping is claimed (*189*).

Isolation of Insoluble Lignin

Concentrated hydrochloric acid and 72% H_2SO_4 are used for analytical determinations of lignin. They are also used to produce lignin for comparison with that produced by other processes, although it is recognized that the values for lignin are subject to limitations and that some changes may have occurred in the lignin during the isolation. It is recognized that low lignin values and high methoxyl content for the lignin represent most closely the true lignin content. The work of Sherrard and Harris (*190*), in which a series of acid concentrations were used and the methoxyl content of the lignin determined, has been repeated and confirmed by Wacek and co-workers (*191, 192*). A minimum value for lignin from extractive-free wood was found. This product contained the highest methoxyl content, somewhat higher than that reported by other investigators (*193*) who did not determine the yield and methoxyl content in the same manner. Lignin in wood that has been subjected to chlorination or oxidation is not quantitatively converted to insoluble lignin by strong acids (*194*).

Isolation of Lignin by a Periodate Method

Purvis and co-workers (*195, 196*) isolated lignin from wood by alternate treatments with sodium periodate at pH 4 and 20°C. and with boiling water at pH 7. Recovery of lignin was 92 to 97% for spruce and 75 to 78.5% for maple, birch, and beech. Analysis showed a carbon content of 55 to 61%. Reaction to ethanolysis, nitrobenzene-alkali oxidation, hydrogenation, and sulphonation was similar to that of lignin in wood

Isolation of Lignin by Dilute Acid Hydrolysis

Wood saccharification processes (*197–200*) leave a residue consisting principally of lignin but containing residual unhydrolyzed carbohydrate, decomposition products and wood extractives. This product, while not pure, could represent a potential raw material for chemical processing.

PROPERTIES OF LIGNIN

The properties of lignin differ with the method of isolation and with the treatment given wood before isolation. A small amount of lignin in wood is alcohol-soluble. The remainder is insoluble either in its original state or because it is attached to carbohydrates. Nord and co-workers (*201*) have increased the amount of soluble lignin from wood by enzyme action of wood-rotting organisms. The increase in solubility may be due to a cleavage of the carbohydrate complex or to chemical changes occurring in the lignin due to the enzyme action. Sulphonation, oxidation, chlorination, and alkali treatment make lignin more soluble. Strong acids appear to make lignin less soluble, although the ratio of soluble lignin to insoluble lignin in isolated sulphuric acid lignin is about the same as the ratio of soluble lignin to insoluble lignin in original wood.

Isolated lignin ranges in color in its solid state from a very light tan to a dark brown, depending on the method of isolation. Because of the light color of certain woods, it is assumed that lignin in its natural state is white or very light tan and that the color of lignin is due either to the presence of colored extractives or to deposits of colored carbohydrate decomposition products. Light-colored lignin forms dark-colored solutions in organic solvents or alkali. The color may be due to action of alkali on the phenolic portion of lignin or to some colored constituent. Enslin (*202*) has shown that lignin from black-wattlewood could be separated into a dark tanninlike constituent, a yellow fluorescent constituent, and a colorless lignin product. Bailey (*203*) found lignin to consist of two or more products on the basis of solubility in methanol and acetone when extracted after impregnation on filter paper.

Ultraviolet Light Absorption by Lignin

Ultraviolet light absorption of lignin solutions and of solid lignin has been used to study nature of lignin. Lange and co-workers (*204–207*) determined the ultraviolet absorption of alcohol-soluble lignin and, on the basis of ultraviolet absorption of spruce wood, estimated that lignin represented 27 to 30% of the wood. Sohn (*208*) concluded that the ultraviolet absorption at 280 mmu may be due to either 5 or 6-member rings. He made a study of furfural and other 5 and 6-member ring compounds and concluded that some degradation products or impurity may hide the true spectra of lignin. Bailey (*209*) used ultraviolet absorption to study four lignin fractions he had separated by chromatography. All fractions had a maximum absorption at 280 mmu and also between 220 and 240, indicating that the difference between fractions were slight.

Schubert and Nord (*210*) found the ultraviolet absorption of lignin that became alcohol soluble after decay to be the same as original alcohol-soluble lignins. Enkvist and Alfredsson (*211*) found hydrogen sulphide-lignin to give almost as high an ultraviolet absorption as lignosulphonic acid. On the basis of shifts in ultraviolet absorption, they concluded hydrogen sulphide-lignin contained 1 phenolic hydrogen for 3 phenyl propane groups. Kraft lignin contained 1 phenolic hydroxyl for 1 phenyl propane group.

G. Aulin-Erdtman and co-workers (*212–217*) studied the ultraviolet absorption of lignin prepared in several different ways and also several model compounds for lignin. The presence of a para propyl-guaiacol unit is indicated. Shifts in the ultraviolet absorption with derivatives indicate the presence of conjugated bonds. The per cent of phenolic hydroxyl in various lignin products is estimated on the basis of the shift of ultraviolet absorption due to alkali. Goldschmid (*218, 219*) has continued the work on the shift in ultraviolet absorption that occurs when lignin preparations are made alkaline. He found a ratio of 1 phenolic hydroxyl group to 2.2 guaiacyl propane groups in pine alkali lignin.

Infrared Absorption by Lignin

In recent years the infrared spectrophotometer has been used to study the infrared light absorption by lignin preparations. Jones (*220, 221*) observed the absorption by "native lignin" and its derivatives and found evidence of strong hydrogen bonding as characteristic of phenolic substances. Infrared absorption spectra of coniferyl alcohol, coniferyl aldehyde, "native" spruce lignin, ammonium lignosulphonate, and methylated spruce lignin were compared with that of a dehydrogenation polymer produced by the action of an enzyme from mushroom on coniferyl alcohol. It was found that the infrared absorption of the dehydrogenation polymer resembled that of spruce lignin (*222*).

Kuhn (*223*) observed the infrared absorption of a large number of carbohydrates and their derivatives. These did not give the absorption given by lignin and by thin wood sections (*224, 225*). Kratzl and Tschamler (*226*) observed that the spectra of lignin had a similarity to aromatic derivatives of cellulose and differed from methyl cellulose and furfural polymers. Nord and co-workers (*227–229*) observed that the infrared spectra of enzymatically liberated lignin was similar to native lignin.

Molecular Weight of Lignin

Molecular weight determinations of lignin and lignin derivatives show that lignin preparations are a mixture of polymers with different degrees of polymerization. Schwabe and Hasner (*230*) found one sample of lignosulphonic acid before dialysis to have a molecular weight of 1865 at 0.9 gram per liter concentration and 2450 at 3 grams per liter concentration; another fraction of a dialyzed product had molecular weights from 5180 to 6660. Ivarsson (*231*) found a molecular weight of about 8000 for lignosulphonic

acid, using a shape factor of 4.6. Resulphonation of the lignosulphonic acid lowers the molecular weight.

Gralen (*232*) measured the molecular weight of a thioglycolic acid lignin and a hydrobromite lignin by the Svedberg ultracentrifuge. A degree of polymerization of 36 was found, or a molecular weight of about 7000. Heating of the thioglycolic acid lignin with thioglycolic acid and hydrochloric acid or with alkali depolymerized the lignin to about half its original molecular weight. "Native" spruce lignin that had been fractionally precipitated from benzene had molecular weights of 2800 to 6700 when measured by osmotic pressure method (*233*).

Various samples of lignin were fractionally precipitated and the molecular weights of the fractions determined (*234, 235*). Their maxima of molecular weight were about 800, 1200, and 1400 to 1700. An alkali lignin showed a portion with a molecular weight of about 400. "Rast" molecular weights of thio and alkali lignin were about 500. Methylated and acetylated derivatives of these same lignins were 1000 and 1500. Deacetylated acetyl-lignin again had a molecular weight of about 450. Methylation with diazomethane gave a product with molecular weights of 1000 and 1500. It was concluded that reactions that replace the phenol hydroxyl group gave higher molecular weights (*236*).

Fractionation of Lignin by Chromatography

Soluble lignin has been subjected to chromatographic separation in attempts to fractionate lignin. Bailey (*237–239*) found that various lignins, when placed on filter paper and treated with a solvent, separated into zones that were heterogeneous. The phenolic fraction from the alkali and "kraft" pulping of spruce wood could be separated by paper chromatography (*240*). Enslin (*202*) separated a "native" lignin into three products by using first a diatomaceous earth and then a cellulose powder in a column. Bland and Gatley (*241*) determined the R_f values for two components of a methanol-lignin from *Eucalyptus regnans* to be 0.05 and 0.95, when a mixture methanol 40 parts, isopropyl ether 80 parts, and water 20 parts was used as the developing agent.

Oak and maple alkali lignins appeared to be homogeneous when subjected to separation by electrophoresis, while "native" pine lignin appeared to contain a mixture of products (*242*).

Fine Structure of Lignin

Jodl (*243*) studied many of the physical properties of lignin. He found the interplanar spacings of cupraammonium lignin to be 9 A × 15 A × 3.9 A, the density to be 1.41, and the surface area of 1 gram of lignin to be 180 sq. in. Water is bound by lyosorption and capillary condensation. Zahn and Lautsch (*244*) studied the x-ray of lignin and model compounds. They were unable to draw any conclusions as to chemical structure from their x-ray data.

Color Reactions of Lignin

Lignin and wood react with amines and phenols to produce colored compounds that are useful in determining the presence of lignin and indicate certain structures for lignin. In 1944 Schutz and Sarten (*245*), after studying the optical properties of wood and lignin, concluded that the formation of colored compounds was not evidence that lignin was performed in the wood. Netien and Névoret (*246*) found that sulphonamides react with the lignin of wood to form a derivative that gives a strong orange-yellow color when acidified with hydrochloric acid. Moerke (*247*) found several amino compounds that give a color with lignin. Isolated lignins react with $SbCl_5$, $SbCl_3$, $AlCl_3$, AsI_3 to form colored addition compounds that Poggi, Serchi, and Berretti (*248*) designate as a "halochromic" reaction.

Adler and co-workers (*249, 250*) studied the color reactions model compounds and found that eugenol and methyl eugenol did not give wood-type color reactions, but veratraldehyde, methyl coniferyl aldehyde, and coniferyl aldehyde gave color reactions. Ultraviolet absorption curves of the color developed by coniferyl aldehyde with phloroglucinol and hydrochloric acid were similar to those for native lignin. The depth of color indicated 1 coniferyl aldehyde group in lignin for 40 methoxyl and 8 carbonyl groups. Ishikawa (*251*) was able to extract the substance responsible for the color reaction in bamboo shoots. He assumed it to be a compound with a coniferyl-aldehyde type grouping. Seifert (*252*) studied the color reactions of a large number of model compounds and lignin with acetyl acetone, phloroglucinol, paraphenylenediamine, and hydrochloric acid.

A color reaction may also be used to study the effect of various reagents on wood (*253*). Pew (*254*) found that the ultraviolet absorption of the color of resorcinol on spruce lignin has the same wavelength as acidified, reduced 4′,7-dihydroxy 3-methoxy flavanone, the same as reduced 2′,4,4′-trihydroxy 3-methoxy chalcone, and the same color as the condensation product of resorcinol and coniferyl aldehyde in acid solution. A yellow color is produced when lignin is treated with strong hydrochloric acid (*255, 256*) and this color is the same as that produced by 5-propenyl coniferyl aldehyde. As the reaction proceeds, the color turns to green, which is made up of a blue and a yellow. The blue color appears to be the result of condensation of the coniferyl aldehyde group with the phenyl propane of lignin in the 6 position. The group responsible for this color is destroyed by oxidation with peroxide.

CHEMICAL REACTIONS OF LIGNIN

Lignin contains many reactive groups that have been the subject of much research in the past. The hydroxyl groups of lignin readily form ethers with various alkylating agents. The nature of the hydroxyl groups may be studied by the reactivity of the ether. Brauns (*257, 258*) prepared alkylated lignins and submitted methylated HCl-spruce lignin to various reactions. Acetic acid with magnesium chloride, phenol, or thiophenol and hydrochloric acid cause the methylated lignin to lose 2 methoxyl groups. Heating with 5% NaOH at 170 to 180° causes no change. Sulphuric acid (72%) splits off 2 methoxyl groups. Thioglycolic acid with hydrochloric acid splits off 1-methoxyl group. On the basis of studies involving methylation of sprucewood and lignin, Freudenberg and Kraft (*259*) propose the formula ($C_{9\cdot93}H_{10\cdot27}O_{3\cdot11}$) for spruce lignin.

In an attempt to prepare lignin derivatives that would be more stable and therefore more suitable for plastics and other uses, several ethers and esters were made (*260–263*).

The reactions of lignin with hydroxyl amine were studied by Nokihara (*264*), who found that treatment of wood with hydroxyl amine and hydrochloric acid in ethanol solution causes 27% of the wood to dissolve. Two nitrogen-containing products are obtained, one with 3 methoxyls per nitrogen and the other 0.95 methoxyls per nitrogen. Lignosulphonic acid produced at high pH lost half its sulphur when treated with hydroxyl amine and hydrochloric acid. The rate of oxime reaction was determined by the rate of hydrochloric acid liberation from the amine.

Bisulphite appeared to react with the hydroxyl of lignin at high pH (*265*) and with both hydroxyl and some ether linkage at low pH (*266*). Hydrogen sulphide appeared to react with hydroxyl and phenolic ether linkages of wood (*267*). Nitration of wood and lignin gave a fraction of the lignin as aromatic nitro-lignin (*268*).

REACTIONS OF CHLORINE AND BROMINE

Chlorine reacts with lignin in wood and with isolated lignin to give a product in which most of the chlorines are loosely combined (*269*). The solubility of the lignin is increased. When wood is chlorinated in the presence of methanol, lignin

becomes soluble as a chlor-lignin (*270*). The use of calcium carbonate to neutralize hydrochloric acid decreases the yield, indicating that hydrolysis accompanied the reaction. Mild chlorination that introduces small amounts of chlorine gives a stable chlorine derivative, while extensive chlorination yields chlorine derivatives from which the chlorine is easily lost (*271*). Commercial wood-hydrolysis lignin was chlorinated (*272*). As long as the chlorine content was below 25 to 27%, no methoxyl was lost. More chlorination removed methoxyl. It appears that chlorination reactions are largely by substitution.

Bromination of various isolated lignins in carbon tetrachloride gave products with about two bromines for each C_{10} of the lignin. Half of this bromine is split off by 10% KOH (*273*). Bromination of lignin model compounds, such as propioguaiacone in chloroform gave the 5-brom derivative, which on degradation yielded 5-brom vanillic acid (*274*). Bromination of lignosulphonic acid gave a soluble product that contained no sulphur and an insoluble product with 40% bromine. Bromination of lignosulphonic acid and several model compounds in alkaline solution yielded bromoform as a result of cleavage of side chains (*275*). When *n*-bromsuccinimide is the brominating agent, a product with 1 bromine per methoxyl is produced (*276*). Derivatives indicate that substitution was in the 5 position of the phenol ring. Sodium hypo bromite gives a bromine derivative of lignin when allowed to react with sprucewood (*277*). This derivative loses two thirds of its bromine on treatment with 1*N* NaOH.

Reaction with Phenol and Thiophenol

Phenol (*278*) and thiophenol (*279*) react with lignin in wood or isolated lignin in presence of hydrochloric acid to give a mixture of condensation products. Oxidation of the resulting products with nitrobenzene and alkali gives products with substitution in the ortho position, indicating that the phenol condenses with the lignin in the ortho position.

A study of the rate of reaction of phenol with lignin and model compounds gave an energy of activation for the reaction of phenol with lignin of 8 to 10 kg.-cal.

Other products also condense with lignin. Amino and nitro-butanol react to give compounds with 1.4 to 1.9% nitrogen (*280*). Maleic acid reacts to give compounds soluble in alkali (*281*), indicating the presence of unsaturated linkages. Maleic and succinic anhydrides react with wood to give an alkali-soluble lignin product and a pulp with less than 1% lignin (*282*).

OXIDATION PRODUCTS OF LIGNIN

Extensive work on oxidation and degradation by oxidation has been carried out in the past 10 years. When oxygen is used as the oxidizing agent, the amount of oxygen absorbed is proportional to the alkali present (*283*). Oxidation of model compounds by gaseous oxygen indicates that the ring opens between the hydroxyl groups (*284*). Electrolytic oxidation of butanol-lignin at a lead cathode gave ketones, acetic and oxalic acid, and substituted aromatic acids (*285*). Oxidation of various lignins with potassium permanganate gave veratric acid, dehydrodiveratric acid, isohemipinic acid, succinic acid, and metahemipinic acid (*286–288*), showing that lignin contains guaiacyl propane units with substitutions in both the 5 and 6 positions.

Oxidation of spruce or maple "native" lignin by chromic acid gave very little acetic acid, indicating no appreciable amount of end-methyl groups. Ethanol lignin gave 1 acetic acid for 4 to 5 C_6C_3 units. Re-ethanolysis increases the number of end-methyl groups by intramolecular changes (*289*). Mild oxidation of coumarones and methylated-ethanol-spruce lignin with chromic acid gave similar products and lead Wacek and Limontschew (*290*) to conclude that lignin contains a coumarone nucleus. Oxidation of hydrochloric acid lignin and vanillin (*291*) with 20% H_2O_2 yielded many of the same products, indicating similar fundamental structure. The action of sodium peroxide on sprucewood gives a light-colored product without much change in composition (*292*). Extractives and lignin account for most of consumption of peroxide. Methylation of sprucewood decreases sodium peroxide consumption.

When firwood is treated for a short time with 10% peracetic acid, most of the lignin dissolves, leaving a pulp. The solution yields lignin products low in methoxyl groups (*293*). Oxidation of lignosulphonic acid (*294*) and of lignin (*295*) with metaperiodic acid required 1 mole of the acid for 195 to 200 grams of lignin. Two to 3 moles of hypochlorite react with cold hydrochloric acid lignin, and 7 moles of hypochlorite react at 95°C. Lignin sulphonate at 95°C. reacts with 10 to 15 moles of hypochlorite (*296*). The reaction causes a change in the ultraviolet absorption curve. Methylation of the lignin decreases the moles of hypochlorite used. When semichemical pulps are treated with chlorine followed by sodium hydroxide and with hypochlorite, most of the lignin and some of the noncellulosic materials are removed (*297*). When wood is treated with sodium chlorite, lignin dissolves (*298*, *299*) and chlorite derivatives of lignin may be recovered from the filtrate.

Oxidation of Lignin with Nitrobenzene

Most oxidation methods used for the study of lignin have been too drastic and products represent end products rather than intermediates that may be of value in determining the structure of lignin. Nitrobenzene has been used as a mild oxidizing agent for many years in reactions such as the Skraup synthesis of quinoline (*300*). Freudenberg and Lautsch (*301*) found that nitrobenzene acted as a mild oxidizing agent for lignin, giving vanillin and related compounds. Recently this work has been extended to model compounds to determine the structures that give high yields of vanillin. With the development of chromatographic methods of separation, some of the work on lignin has been repeated to determine the various products formed. Wacek and Kratzl (*302*) oxidized several hydroxy and keto phenyl propane compounds with nitrobenzene. Compounds with a C=O on a side chain next to the phenyl group gave acids rather than aldehydes. Compounds with a parahydroxy phenyl grouping gave higher yields of aldehydes (*303*).

Pearl and Lewis (*304*) studied the reduction of nitrobenzene by sulphite spent liquor to determine the maximum yield of products. Hibbert and co-workers (*305*, *306*) studied the oxidizing action of nitrobenzene on many different plants to determine the yields of vanillin and syringaldehyde. They found that the ratio of products formed offered a new means of classifying plant materials. Various chemical treatments decrease the yield of vanillin (*307*) from lignin as follows: alkali lignin > 70% H_2SO_4 lignin > degraded lignin > methylated lignin.

Cohen (*308*) reported *Eucalyptus regnans* yielded 4 times as much syringaldehyde as vanillin and *E. marginata* 1.5 times as much syringaldehyde as vanillin. Bland, Ho, and Cohen (*309*) separated the products of nitrobenzene oxidation of various eucalypt woods by chromatography and were able to obtain much better separation.

Stone and Blundell (*310*) developed a nitrobenzene oxidation method for lignin using small samples (40 to 50 mg.). The products were separated by chromatography, extracted, and converted to a 2,4-dinitrophenyl hydrazine and then determined with a Beckman spectrophotometer. When wheat straw "native" lignin was fractionated (*311*), the ether-soluble fraction gave a different ratio of vanillin to syringaldehyde than the ether-insoluble fraction.

Leopold and co-workers (*312*, *313*) conducted extensive experiments using nitrobenzene oxidation. Wood decayed by brown rot gave low yields of vanillin. When the products of the oxidation of spruce were separated chromatographically

a large number of other products, such as parahydroxy benzaldehyde and 5-formyl vanillin, in addition to vanillin and syringaldehyde were shown to be present (*314*). Total yield of aldehydes recovered based on the methoxyl recovered in the aldehyde was 31 to 32% (*315*). Aldehydes from hardwoods were about 75% syringaldehyde. Low sulphonated lignin (*316*) appeared to give higher yields of vanillin based on methoxyl recovered than did wood, but this was because some nonlignin methoxyl had been lost in the preparation of the low sulphonated lignin. Soluble beta lignin sulphonic acid (*317*) gave higher yields of vanillin (33.0, 36.0, and 38.3%) as the molecular weight of the lignin decreased. Wood attacked by termites (*318*) left the lignin relatively unchanged and gave almost the same yield of vanillin. Methylation of lignin (*319*) by diazomethane, methanol and hydrochloric acid or dimethyl sulphate decreased the yield of vanillin by preventing the splitting of phenolic ether linkages in lignin. Several lignin models were condensed with resorcinol (*320*) and the yield of vanillin by oxidation was determined.

De Stevens and Nord determined the nitrobenzene oxidation products of bagasse lignin (*321*) and of "native" and enzyme-liberated lignins (*322*). They consider there is evidence for 1 tertiary hydroxyl, 1 alcoholic hydroxyl, 1 phenolic hydroxyl, 1 enolizable carbonyl, and 1 cyclic ether in a lignin unit.

Alkaline-nitrobenzene oxidation of lignin (*323*) dissolved by the chlorite process for holocellulose gave vanillin, 6-chlor vanillin, and vanillic acid; no 5-chlor vanillin was found, indicating substitution of chlorine was not in the 5 position as proposed for the action of chlorine on lignin.

Hlava and Brauns (*324*) concluded that the low yield of veratraldehyde when hydrochloric acid lignin and methylated hydrochloric acid lignin were oxidized was not proof that little veratraldehyde was formed, because veratraldehyde is demethylated by oxidation with nitrobenzene.

Oxidation with Metal Oxides

Pearl has used metallic oxides for the oxidation of lignin; mercuric oxide and alkali yield vanillin, acetovanillin, vanillic acid, and guaiacol (*325*). Calcium lignosulphonate yields the same products with mercuric oxide or silver oxide (*326*). Treating of kraft or sulphite spent liquor lignin with hot sodium hydroxide and mercuric oxide produces 5-(hydroxymercuri)-vanillin in addition to other products (*327*). Changing the ratio of lignin to silver oxide and of lignin to sodium hydroxide resulted in yields of vanillin ranging from 9.0 to 28.2% (*328*). The highest yield (31.4%) resulted with a silver oxide to lignin ratio of 3.75 and a sodium hydroxide to lignin ratio of 21.0 at 83°. A similar experiment with copper oxide gave a maximum yield at 190°. Improved separation of the products from the oxidation of sulphite spent liquor with silver oxide showed the presence of 5-carboxy vanillic acid (*329*) in addition to products noted before. With copper hydroxide as the oxidizing agent, 5-carboxyvanillic acid, 5-carboxy vanillin, dehydrodivanillic acid, and dehydrodivanillin were found in addition to other products (*330*). Chromatography aided in separation of products, gave recoveries up to 99% (*331*), and showed the presence of several other related compounds (*332*).

CLEAVAGE OF LIGNIN HEATED WITH ALKALI

Crude lignin heated with calcium hydroxide in 90% ethanol at 320° for 5 hr. gave a tar fraction containing 24% phenols and 2.5% acids (*333*). Several isolated lignins and sprucewood yielded vanillin and acetaldehyde when heated with alkali. Sulphonated lignin gave highest yields (*334*). Formaldehyde also appears as a cleavage product (*335*). Similar experiments with model compounds indicate the formaldehyde originates in the side chain (*336*). The alkali-cleavable groups appear to be masked in isolated lignins. An increase in alkali concentration causes some increase in cleavage.

HEATING WITH HYDROCHLORIC ACID AND AN ALCOHOL

Bailey (*337*) found seven low boiling compounds in 27.7% yield in the products resulting from the heating of butanol-lignin with 50% butanol containing 0.25*N* HCl for 3 hr. at 100°C. Heating of methylated sprucewood with methanol and hydrochloric acid gave a methanol lignin with 30.6% methoxyl, and with phenol gave a product with three phenol groups and 16.4% methoxyl (*338*).

THERMAL DECOMPOSITION

Lignin residues from dilute acid hydrolysis of Douglas-fir wood decomposed at 375 to 400° to yield a char in 55 to 66% yield and 5.2 to 8.9 of a settled tar. The tar was 82% soluble in petroleum ether and contained 35.5% phenolic, 32.8% neutral, and 7 to 8% acidic substances (*339*). Fractionation of the constituents of the tar yielded phenols and catechols (*340*). Heating of a sulphonated copper-oxide-lignin in an oil bath at 90 to 180° split off sulphur dioxide. At 250°, 69.7% of the sulphur was lost (*341*).

CLEAVAGE BY SODIUM METAL IN LIQUID AMMONIA

Lignin from various sources was 89% decomposed by sodium in liquid ammonia to yield 50% water-soluble products, 19% acids and phenols, 8% ether-soluble neutral compounds, and 11% high-molecular-weight substances (*342*). A cupraammonium lignin at −33° yielded monomolecular products that indicate an ether linkage was cleaved (*343*, *344*). When the mixture of lignin and sodium in liquid ammonia was allowed to stand 7 to 8 days, the solution became colorless and the product contained an ether-soluble oil (15.7%) and a soluble lignin (45%) with 16% methoxyl (*345*).

HYDROGENATION OF LIGNIN AND WOOD

Work on the hydrogenation of lignin has been continued. Bailey (*346*) hydrogenated butanol-lignin over Raney nickel. One mole of hydrogen was absorbed by 28 grams of lignin. Several low-boiling products were identified. Stump (*347*) hydrogenated sulphite spent liquor, obtaining neutral compounds, phenols, and acids. Hachihama and Jodai (*348–351*) hydrogenated wood and lignin to low molecular weight substances containing phenols and neutral compounds. Matsuda (*352*) hydrogenated lignin, obtaining a phenolic product 68.5% soluble in ether. Heating of lignin with cyclohexanol (*353*) at 300° converted some of the lignin to soluble products and some cyclohexanol to benzene. Methanol-aspen-lignin was hydrogenated over Raney nickel in water at 250° (*354*), producing substituted cyclohexanols, glycol derivatives, and unidentified products. Products from the hydrogenation of alkali-hardwood lignin over copper chromite at 300 to 327° contained methanol, phenolic substances, tar acid, neutral oils, and heavy oils. The phenolic fraction contained phenol, cresol, ethyl phenol, propyl phenols, and catechols (*355*). Wood hydrolysis residue was hydrogenated (*356*) to neutral oils, acids, phenols, and high-boiling products.

Lignin was hydrogenated by heating in the presence of an alcohol and sodium hydroxide (*357*), giving high yields of neutral compounds with a wide boiling range. Lignosulphonic acid yielded phenols at 260°C. (*358*). Lignin preparations heated with butanol and alkali gave catechols, monohydric phenols, and neutral oils (*359*, *360*). Hydrogenation of wood at 150 to 225° in the presence of a small amount of alkali and a catalyst converted lignin to water and alcohol-soluble products (*361*). If the reaction is interrupted at an intermediate stage, a chloroform-soluble lignin is ob-

tained (*362–364*). If this soluble lignin is rehydrogenated, cyclohexanol derivatives are produced. Granath and Schuerch (*365*) were able to isolate a dimer of the C_{10} lignin-building unit from this chloroform-soluble lignin. Hydrogenation of synthetic model compounds and dimers gave products similar to those obtained from lignin (*366*). Products from the hydrogenation of aspen wood and wheat straw (*367*) were separated by chromatography. Ethyl and hydroxy ethyl derivatives were found among the products. Soluble lignin obtained by mild hydrogenation of aspen was oxidized by nitrobenzene, yielding aldehydes (*368*). The ratio of syringaldehyde to vanillin was higher than that from wood. Hallonquist (*369*) hydrogenated wood under a wide range of conditions and determined the yield of low-boiling products. No products were identified.

BIOLOGICAL DECOMPOSITION OF LIGNIN

An ultraviolet spectrographic method was developed for estimating the loss of lignin sulphonate by the action of fungus growth (*370*). Results confirm the observation that fungi decompose lignosulphonate.

Enzymes are found to decompose lignin by demethylation and by oxidation (*371*). Wood-rotting fungi grew on lignin as the sole source of carbon (*372, 373*). Fungi did not appear to use lignosulfonate but did remove it from solution (*374*). Residues from the action of fungi on wood resembled true lignin and contained 12.7 methoxyl (*375*). When wood-destroying fungi grew on alpha conidendien or vanillic acid as the sole source of carbon the products included galactose, glucose, mannose, ribose, and rhamnose (*376, 377*).

Fischer (*378*) observed that chromogenic and fluorescent groups of bacteria in soil decompose lignin in the presence of nitrogen, oxygen, and growth factors. Lignin from chestnut and acorns yielded several compounds when acted on by lignin-destroying fungi. Vanillin was among the products (*379*). Wood subjected to fungus attack could be molded under heat and pressure. Analysis shows a loss of methoxyl (*380*). Leopold (*318*) found that wood underwent about the same degree of decomposition in passing through the intestinal tract of a West Indian termite as in 8 months exposure to fungus attack.

CONTRIBUTION OF MODEL COMPOUNDS TO THE CHEMISTRY OF LIGNIN

Considerable progress has been made in the chemistry of compounds believed to be related to the lignin-building unit. A number of monomeric products were produced in the ethanolysis of wood. Hibbert's students have synthesized many of these and similar products and have studied their reactions. One of these, 3-hydroxy-1-(4-hydroxy-3-methoxy phenyl)-1-propanone, was methylated and ethylated; on oxidation with nitrobenzene it yielded vanillin derivatives, and on treatment with ethanol and hydrochloric acid gave a ligninlike polymer (*381*). The ultraviolet spectra of several ethanolysis products and related compounds indicated a relationship to 4-hydroxy-3-methoxy cinnamic aldehydes (*382*). The 3,4-dimethoxy phenyl derivative was synthesized and that too was converted to a ligninlike polymer (*383*). The acetyl derivatives were shown to undergo ethanolysis (*384*). Removal of bromine from the 1-brom-propanone and acetyl from the 1-acetyl propanone gave propanone and 1,2-propanedione, which suggested a means of cleavage of groups of lignin (*385*). A triacetate was hydrolyzed to the 1,2-propanedione (*386*). A 3-hydroxy-1-(4-hydroxy-3-methoxy)-2-propanone was synthesized. This was thought to be a prime lignin progenitor (*387*). Ethanolysis of the 3-hydroxy compound was carried out by Gardner (*388*).

A group of Swedish researchers have carried out extensive research on model compounds related to lignin. Model compounds form 5-brom derivatives, but lignin forms 6-brom derivatives, which may indicate the 5 position has been filled by condensation with the side chain of other groupings (*389*). Substituted benzyl alcohols were sulphonated to sulphonic acids. Their presence in pulping liquor inhibited sulphonation of pine heartwood (*390*). When there was a parahydroxy present, sulphonation and condensation with phenols was closest to that of lignin (*391*). Pinoresinol, which is present in extractives of wood, was sulphonated and subjected to several reactions used for lignin and found similar to lignin (*392*). Aromatic keto and hydroxy polyethers were oxidized by nitrobenzene and the yield of vanillin determined. They were also sulphonated. In the process ethers were changed to alcohols which react (*393*).

A series of substituted acetoguaiacones were sulphonated by replacing the hydroxyl group and gave amorphous sulphonic acids (*394*). Polymers of aromatic keto and hydroxy polyethers were 90% sulphonated at pH 1.7 to 1.8 (*395*). At 180° they were oxidized by nitrobenzene and alkali to a high yield of vanillin (*396*). Oxidation of polyethers proceeds by fission of ether linkages and yields products similar to lignin. If the groups are combined by carbon-to-carbon linkages, yields are low or none. Only benzyl-alcohol type alcohols or ethers give good yields of vanillin. Compounds having the hydroxy group on the beta carbon atom gave little or no vanillin (*397*). It was also found that parahydroxy benzyl alcohol or ether groups were sulphonated but, if the aromatic parahydroxy group was alkylated, sulfonation was hindered (*398*). Dehydrogenation polymerization of coniferyl alcohol lead to the conclusion that condensation was of ether or carbon-to-carbon type. The ether-type condensation products gave good yields of vanillin; the other did not. Lignin may have both types of condensation (*399*).

Enkvist and Moilanen (*400, 401*) subjected several model substances to hydrogen sulphide and sodium hydrosulphide. Compounds such as eugenol, isoeugenol, and vanillin form only small amounts of sulphur compounds at pH 7. At 160° sodium hydrosulfide gave amorphous substances. Vanillil alcohol reacts with hydrogen sulphide to give a disulphide that resembles lignin-hydrogen sulphide compounds. Benzyl alcohol and benzyl alcohol ethers activated by a paraphenolic hydroxyl or orthohydroxyl react with hydrogen sulphide. Ether linkages are split by sodium hydrosulphide. A shift takes place and creates a new carbon-to-carbon bond.

Wacek, Kratzl, and co-workers have carried out numerous researches with model compounds having 3 carbons in the side chains (*402–413*). They found that parahydroxy phenyl ethyl ketones sulphonated in the alpha and beta position to carbonyl group. A carbonyl group in conjugation with a double bond is readily sulfonated. Ketols in 1,3 position on a side chain react. In 1,2 position they do not. There is little oxidation by nitrobenzene if a carbonyl group is in the beta position; if in alpha position, it reacts. A parahydroxy group increases reaction. Compounds containing the reversible aldol-type grouping split to give aldehydes. Model compounds with labeled carbon were synthesized and gave the same reactions as other lignin model compounds. They offer a further means of lignin study.

Freudenberg and co-workers have also carried on experiments with lignin model compounds (*414–417*). Compounds with hydroxy groups on a beta carbon on the 3 carbon side chain give formaldehyde when heated with alkali or mineral acids. Ligninlike polymers have been made from *d-l*-pinoresinol and coniferyl alcohols. Several derivatives of the polymers have been made, indicating a relationship to lignin.

Pearl (*418–420*) studied the reactions of vanillin and compounds related to vanillin to determine the types of derivatives that may be produced and the manner in which they are related to lignin. Zentner (*421*) subjected several model compounds, including propiovanillone and 2,4-dehydroxy-3-methyl chalcone, to the action of sodium hydrosulphide for

4 to 5 hr. at 160°C. Only the compounds with hydroxyls reacted to give sulphur derivatives. A small amount of demethylation occurred. Pew (*422, 423*) studied the color reactions of several model compounds and found that some derivatives of flavanones and coniferyl aldehyde gave the same color as native lignin.

STRUCTURE OF LIGNIN

Many proposals have been made for a structure for lignin. Most of these proposals are lacking in some respect. Lignin readily undergoes polymerization and condensation in the presence of most of the reagents used for its isolation and, therefore, there is no certainty that the material studied is the same as that in wood. Studies on lignin in whole wood substance are limited because of the masking action of other wood constituents.

On the basis of a study of the residual substance from the chlorite decomposition of wood, a carbohydrate guaiacyl complex structure has been proposed (*424*). Freudenberg and co-workers (*425–429*) carried out extensive work to determine the various reactive groups in lignin and concluded lignin is a polymer of coniferyl alcohol; and for each C_9 in spruce there are 0.34 primary hydroxyl groups, 0.34 secondary hydroxyl groups, 0.26 phenolic hydroxyl groups, and 1.49 oxygens not in methoxyl or hydroxyl groups; 0.64 of these hydroxyl groups are phenolic ether groupings. Richtzenhain (*430, 431*) oxidized methylated wood and methylated lignin, obtaining aromatic compounds, some of which indicated condensation in 5 position and others in 6 position. This indicates that lignin is aromatic and condensed in the 5 and 6 positions. He contends that the splitting of ether rings does not play a part in the reaction with bisulphite, thioglycolic acid or alcoholic-hydrochloric acid solutions.

In many cases with aromatic compounds it is possible to increase the phenolic character of compounds by chlorination. Sohn (*432*) found the phenolic character of lignin was not increased by chlorination. Freudenberg has proposed coniferyl aldehyde as the source material for lignin, but Adler and Haggroth (*433*) believe some phenyl propane derivative other than coniferyl aldehyde is responsible for part of the vanillin and acetaldehyde formed from lignin on the basis of their study of the alkali treatment of lignin. A structure for lignin with alpha glyco groups has been proposed. Lindgren and Saeden (*434*) subjected lignin to periodate oxidation but obtained no evidence of formaldehyde which should result from a glyco oxidation. The ultraviolet absorption of several model compounds has been compared with lignin; these give evidence for an aromatic structure and also evidence for the number of aromatic groups in lignin (*435*).

Leopold (*436*) recently reviewed work on lignin chemistry and believes a guaiacyl structure for softwood lignin has been confirmed. Guaiacyl groups are connected by ether or carbon-to-carbon linkages and all or most all of the reactive groups consist of alpha hydroxy or ether groups in the side chain activated by phenolic parahydroxy groups. Schutz, Sarten, and Meyer (*437*), however, do not believe that isolated lignin can be used to interpret structure because of changes occurring in isolation.

A study of model compounds has lead Kratzl (*438*) to believe that the formaldehyde and acetaldehyde obtained in the alkaline cleavage of lignosulphonic acid originates from side chains of aromatic compounds. Sorgato and Scipioni (*439*) determined the various functional groups in lignin and considered their relationship to structure. Kleinert (*440*) found that previous oxidation with hydrogen peroxide prevented or lessened formaldehyde formation in the alkali cleavage of lignosulphonic acid. Oxidation (*441*) of birchwood with hydrogen peroxide affected the copper number, but did not affect it on pine.

Several investigators have been interested in the methoxyl of wood and lignin and its relationship to structure. Wacek and co-workers (*442, 443*) studied the methoxyl content of wood and conclude that only 85% of the methoxyl is contained in isolated lignin and that a part of the remainder may be contained in a soluble lignin. Migita and Nakano (*444*) found that the methoxyl of lignin showed the reactivity of aromatic methoxyl. Analysis of bamboo shoots (*445*) at various ages indicate that methoxy groups increase and free phenolic groups increase with greater lignification. Work on other bio-methylation processes indicate methylation of lignin may occur by transmethylation (*446*). Merewether (*447*) found the methoxyl content of isolated thiolignin higher if the wood was previously extracted with alkali.

Search for other groups in lignin has shown the presence of isobutyl groups (*448*). On the basis of extractives it may be expected that a safrole may be incorporated in lignin of sassafras, but the lignin did not yield piperonyl derivatives (*449*). A polyflavanone structure has been proposed for lignin (*450*). Russel (*451, 452*) polymerized vanillin-monoacetate to obtain a polymer that he considered identical with sprucewood lignin. The intermediate (*453*) of this synthesis was shown later to have a different structure than that proposed, which was not related to lignin. Goldschmid and Maranville (*454, 455*) found one phenolic group in 2.1 to 4.3 C_{10} lignin units in various lignin products by an ultraviolet method based on the shift in color as compared with eugenol and conedendrin. Kurschner (*456*) used a nitration method and concluded that spruce contains only 8.5% aromatic lignin. He contends lignin in excess of this amount obtained by use of acid or alkali is formed from carbohydrates during the isolation process.

BIOSYNTHESIS OF LIGNINLIKE SUBSTANCES

Polymerization of substituted phenolic compounds to amorphous products in the presence of mushroom dehydrogenase has been known for many years (*457*). In a study of possible synthesis of lignin in the spruce tree, Hibbert and co-workers (*458*) hydrogenated 2 to 3-week-old spruce buds but did not obtain propylcyclohexanols; however, $3^1/_2$ to 4-month-old tips did yield propylcyclohexanols. They concluded lignin must be formed by some type of polymerization later in the age of the tree.

Freudenberg and Richtzenhain (*459*) calculated a lignin formula on the basis of guaiacyl derivatives and assumed that the loss of phenolic hydroxyl must be due to condensation by dehydrogenation. Dehydrogenation polymerization of 5-methoxyl-pyrogallol-1,3-dimethyl ether occurs when oxygen is passed through a solution of the compound in the presence of mushroom extract (*460*). In the presence of mushroom extract and air guaiacyl and syringyl compounds polymerize (*461*). At pH 8 polymerization of phenolic compounds in the presence of mushroom extract to an amorphous polymer was rapid (*462*).

In 1948, Manskaya (*463, 464*) published the discovery of a peroxidase in the cambial layer of conifers that caused polymerization of phenolic compounds. He found that coniferyl alcohol and vanillin were present in the cambial layer. Nord (*465*) observed that a methyl-paramethoxy cinnamate was formed from glucose and xylose by *Lentinus lepideus* and postulated its relationship to lignin and to the possibility of polymerization to lignin. Freudenberg (*466–468*) continued work on the dehydrogenation polymers of coniferyl alcohol which formed an amorphous polymer that reacted much as spruce lignin. Coniferin in the presence of emulsion (to hydrolyze the glucose group) gave a similar polymer by dehydrogenation polymerization (*469*). Methylated spruce lignin isolated by formic acid and the methylated polymer of coniferyl alcohol had similar ultraviolet absorption curves (*470*). Carbon content was also similar, but methoxyl and hydroxyl content differed. Sinapyl and coniferyl alcohol formed copolymers by dehydrogenation in the presence of mushroom extract (*471, 472*). Coniferyl methyl ether also

polymerized (*473*) and was subjected to many lignin reactions. A localized betaglucosidase was found in the cambium that can free coniferyl alcohol so that it can react in the presence of wood peroxidase to form polymers (*474, 475*).

Coniferyl alcohol and 3,4-dihydroxy cinnamyl alcohol form copolymers that have ligninlike properties. Such a polymer may account for the low methoxyl in lignin (*476*). Dehydrogenation polymers containing C^{14} have been synthesized (*477–479*). Formaldehyde formed by cleavage of the product was radioactive, indicating it came from the primary (COH) grouping. Isohemipinic from the product is inactive and metahemipinic is one-third active. Radioactive coniferin placed in the cambium of a tree was converted to lignin containing the entire activity (*480*). Pinoresinol has been isolated as a product formed by dehydrogenation polymerization of coniferyl alcohol. On further treatment pinoresinol forms an amorphous ligninlike product (*481*).

Baruah and Swain (*482*) formed an amorphous polymer from catechol in the presence of mushroom enzyme. Eugenol and hydrogen peroxide catalyzed by peroxidase formed a ligninlike amorphous polymer (*483*). When wheat seedlings (*484*) were exposed to radioactive carbon dioxide, both cellulose and lignin contained C^{14}. Wacek, Hartel, and Maralla (*485*) added coniferin to spruce tissue culture in vitro but could not conclude that coniferin was converted to lignin. Formic acid and the methyl group of methionine with C^{14} were transferred in growing plants to methoxyl groups of lignin. The rate of transfer from methionine was 26 times faster than the rate from formic acid, indicating that methylation of lignin may be by way of methionine (*486*).

UTILIZATION OF LIGNIN

Many writers have reviewed the uses of lignin (*487–495*) for such things as tanning agents, core binders, rubber compounding agents, surface-active agents, for production of chemicals, plastics, water conditioners, for storage batteries, soil improvement, oil drilling, and protein precipitants. Pritchard and Daily (*496*) described the use of lignin in storage batteries. Lignin may be used as a soil-stabilizing agent in road building (*497, 498*). Soluble lignin or insoluble lignin after being made soluble by the action of alkali and an oxidizing agent may be coprecipitated with rubber to provide reinforcing properties (*499–506*). Lignin and lignin derivatives have been tested, not too successfully, for plastics (*507–511*). Lignin has cation bonding value that make it useful for water purification. The property can be increased by condensation with various amines (*512, 513*). Lignin and composted sawdust have soil-building value (*514–517*). Lignosulphonic acid and its derivatives are suitable surface-active agents for producing emulsions (*518–522*). Protein may be precipitated from solution by treatment with lignin (*523, 524*).

Lignin under water and protected from air is very resistant to decomposition (*525*). Exposure to air increases rate of decomposition and the rate is increased further by the presence of algae (*526*). Heating of lignin with various solvents increases its activity (*527*).

Lignin is a source of many fine chemicals, including vanillin, that may be used for the preparation of many other chemicals. Substituted amines and ureas may be made from vanillin (*528*). Several derivatives were made from vanillil (*529*) and vanillin (*530*). Some of these have medicinal value (*531*). Vanillin may be removed from solutions from the alkaline hydrolysis of sulphite spent liquor containing as little as 0.2% vanillin by the use of an anion exchange resin at pH 7 (*532*). Vanillin may be extracted from alkaline lignin-containing liquors without acidification by tertiary butyl alcohol (*533*). Pearl (*534*) obtained vanillic acid in high yield from calcium lignosulphonate by oxidation with silver oxide in the presence of sodium hydroxide. The Ontario Paper Co. (*535*) has developed a process for producing vanillin from sulphite spent liquor using lime instead of sodium hydroxide. The vanillin and other oxidation products are extracted by toluene. Vanillin is removed from the toluene by caustic and distilled to give a product with 97% vanillin.

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Progress in the Production of Refined Cellulose

EDWIN C. JAHN

THE production of dissolving pulps and special alpha pulps from wood has increased from about 300,000 tons in 1940 to about 700,000 tons in 1952 and 1953. Additional capacity of about 300,000 tons has come into production this year. Furthermore, there are imports amounting to around 200,000 tons, so that the total consumption is in the neighborhood of $1^1/_4$ million tons. Rayon and the cellulose derivatives have shown impressive increases in production over the past three decades. Among the newer products which have made outstanding growth are staple fiber, acetate filament, mixed ester products, and acetate film.

Wood cellulose is now the principal raw material for cellulose derivatives. Nearly all viscose rayon is made from wood pulp. The second source of cellulose for cellulose derivatives is cotton linters (chemical cotton). Cotton linters find preferred use in certain products such as cellulose acetate for plastics or high-tenacity rayon. For other applications cellulose acetate is more often made from wood cellulose.

Wood, as a source of cellulose, offers many economic advantages over cotton or other annual plants. Greatest of these is its compactness or yield of cellulose per unit volume of space, resulting in (1) much greater yields per acre, (2) simpler transportation, (3) simpler storage problems, (4) year-round supply, and (5) reduced labor. However, wood is a very heterogeneous substance chemically compared to cotton, which is mainly cellulose. Isolation of a suitable cellulose for chemical conversion from wood required, first, a carefully controlled pulping process to remove most of the lignin and a portion of the hemicelluloses, and second, a refining process consisting of multiple-stage bleaching and alkali extraction, to remove the remaining lignin, coloring substances, and more of the lower molecular weight polysaccharides.

EDWIN C. JAHN, State University of New York College of Forestry, Syracuse, N. Y.

Until recent years dissolving pulps have been made exclusively by the sulphite process from coniferous trees, mainly spruce and fir, because of the low pentosan and high alpha-cellulose contents and easy bleaching of such pulps. Today, a much broader range of wood species is used and both the sulphite and the sulphate pulping processes are used. The major recent trends in the production of refined cellulose are in (1) species used, (2) pulping methods, and (3) pulp purification.

WOOD SPECIES AND THE SULPHITE PROCESS

The development of good pulps from other wood species has gone hand in hand with improvements and modifications in pulping processes. In the United States, the supply of spruce and fir has greatly dwindled, and this has stimulated investigations for producing suitable pulps from other wood supplies.

It should be borne in mind that the pulping process only constitutes the initial step in the production of high quality pulps and that it must be coordinated with the purification processes that follow. The sulphite process plus modifications in pulp purification have not been too difficult to apply to certain other coniferous species, the more important of which are westerm hemlock, Douglas-fir, and southern pines. In the case of the southern pines, the problem is to produce a resin-free pulp. This is done by using young growth trees, prior to their formation of resinous heartwood, and by screening out the epithelial resin-bearing cells which are present.

An important contribution to overcoming difficulties in the sulphite pulping of certain coniferous woods, especially the heartwood of several of the pines, has been made by Hägglund (*1*) and his co-workers and by Erdtman (*2*). Hägglund found that there are inhibitors present in the extractable constituents of these species. These were found by Erdtman to be 3,5-dihydroxytransstilbene (pinosylvin) and its monomethyl ether.

When woods containing pinosylvin or other reactive phenols are heated with normal sulphite cooking acid, two reactions take place with the lignin, sulphonation and condensation with the phenol. The latter takes place at a much higher rate than the sulphonation in a strongly acid cooking liquor. This condensation gives rise to large insoluble three-dimensional complexes. A way around this difficulty can be obtained by applying the two-step procedure invented by Graham in 1882 (*3*). In the first step the wood is impregnated by a neutral sulphite cooking liquor, during which sulphonation takes place at a much higher rate than condensation. In the second step, the partially sulphonated wood is heated with normal sulphite cooking acid, during which sulphonation is completed followed by delignification. Some condensation also occurs, but the product is soluble because of the high degree of sulphonation.

Douglas-fir wood is difficult to pulp by the conventional calcium-base sulphite cook. Pew (*4*) isolated a phenol, dihydroquercetin (toxifolin) from the heartwood. This compound appeared to have some inhibiting power, though other factors also appear to contribute to the sulphite pulping resistance of this species, since the resistance is largely dependent upon the base used in the cooking liquors. Soda-base liquors facilitate the pulping (*5*) of Douglas-fir. Hoge (*6*), in a recent study of this problem, confirms the theory that dihydroquercetin is a mild pulping inhibitor, causing the lignin content and permanganate number of the pulp to increase. However, he showed that the inhibition was not due primarily to the formation of lignin condensation product, since longer cooking times removed more of the lignin, *i.e.*, the residual lignin can be further sulphonated. Hoge found that most of the dihydroquercetin reacts with the bisulphite to form quercetin and thiosulphate. Thiosulphate promotes the decomposition of bisulphite, though in the early part of the cook the wood reduces the concentration of thiosulphate, so that the effect is negligible. Both dihydroquercetin and quercetin are only mild pulping inhibitors. However, their presence in pulps causes a yellow color, a high permanganate number, and changes the ultraviolet curves from lignin filtrates. According to Hoge, the principal difficulty in pulping Douglas-fir is the slow rate of lignin removal which allows the bisulphite decomposition (proceeding at a normal rate) to attain serious proportions before delignification is completed. This decomposition occurs mainly toward the end of the cook, forming sulphuric acid which precipitates calcium sulphate, reducing the available base before the end of the cook. The use of soluble-base liquors largely avoids these difficulties, since the base is not precipitated and remains available for the completion of the pulping reaction.

Additional data have been obtained by Richter and Pancoast, Jr. (*7*) demonstrating the different behavior of wood species to sulphonation. Long sulphonation periods with 10% SO_2 at room temperature show white birch to sulphonate more slowly than conifers. When this presulphonation (2 weeks) is followed by a digestion at 120°C. for 8 hr., the results shown in Table I were obtained:

Refined pulps for chemical conversion are now being made from hardwoods in increasing amounts. It is

Table I

Species	*Yield, %*	*Lignin, %*	*Original lignin removed, %*
Eastern spruce	44.2	1.6	97.6
Western hemlock	46.5	1.4	97.9
White birch	43.4	3.4	94.1
Southern pine	45.2	8.7	87.6
Douglas-fir	49.7	23.8	64.7

reported that viscose-grade pulps are being made from northern hardwoods by the sulphite process in this country and Canada, from birch in Sweden, from beech in Germany, and an acetylation grade sulphite from aspen in Sweden.

A recent study (*8*) has been made of dissolving pulps from aspen by both the sulphite and sulphate processes at the U. S. Forest Products Laboratory. For the sulphite process, an ammonia-base cooking liquor, relatively low in combined sulphur dioxide to facilitate hydrolysis of the hemicelluloses was used (see Table II). The pulp purified by hot alkaline extraction made a satisfactory acetate yarn.

An interesting development in Finland is a two-stage pulping process (*9*) suitable for the production of both paper and high alpha pulps. The first stage involves cooking with a sodium-base liquor containing high free sulphur dioxide (pH around 3) followed by the second stage which involves the injection of sodium carbonate solution under pressure into the digester until the liquor is about pH 8. The temperature is elevated to take advantage of the kinetics of the alkaline delignification reaction.

WOOD SPECIES AND THE SULPHATE PROCESS

The alkaline processes and their modifications lend themselves more easily than the sulphite process to a wider range of wood species. It is reported that, besides spruces, firs, hemlock, and several pines, various hardwoods including gums, chestnut, beech, and birch are made into chemical conversion pulps by alkaline pulping processes in North America and Europe.

Probably the single most important development (*10–16*) during the past 25 years in pulping woods for dissolving grade pulps is the prehydrolysis step followed by kraft pulping. Ordinary kraft pulps, especially from hardwoods, produce viscose solutions difficult to filter (*12*) and hazy acetate syrups (*17*). By subjecting wood chips to a mild acid prehydrolysis, good viscose or acetate pulps may be prepared from a wide range of woods by the kraft process. By this method, high pentosan containing materials may be successfully used, such as the northern hardwoods, gums, bamboo (*18, 19*), eucalyptus (*20*), aspen (*8*), and others.

In the recent studies of aspen by the U. S. Forest Laboratory (*8*), the wood was prehydrolyzed by water at 170°C., followed by a kraft cook. Total pulping time was $2^1/_2$ hr. ($1^1/_2$ hr. at 170°C.). The yield and properties of the pulps, before and after purification and compared to ammonia-base sulphite pulps from aspen are shown in Table II.

The aspen pulps prepared by the prehydrolysis-kraft process produced a satisfactory rayon tire cord yarn and an acetate yarn as strong as from commercial softwood sulphite acetylation grade pulps. The filterability of the viscose solution is sensitive to the amount

Table II

	Yield, %	Alpha, %	Pentosans, %	Viscosity, cp.
Prehydrolysis-Kraft				
Unbleached pulp	42	92	2.8	37.6
Purified by cold alkaline extraction	38.2	97.3	2.0	18.4
Purified by hot alkaline extraction and NaOCl	37.6	94.7	2.2	12.5
Purified by hot alkaline extraction and ClO_2	37.7	95.5	2.5	16.3
Ammonia-Base Sulphite				
Unbleached pulp	51	87	5.1	37.4
Purified by cold alkaline extraction	44.4	96.3	0.3	22.0
Purified by hot alkaline extraction	37.7	94.4	1.5	30.0

of carbon disulphide used in xanthating. This appears to depend upon the degree of prehydrolysis (*21*) and if the latter is insufficient, more carbon disulphide is required to obtain suitable filterability. Furthermore, there is a relationship between acetate haze characteristics and the pentosan content of the pulp. This relationship has also been previously noted by McKinney (*17*) and has been further supported by the recent work of Bradway (*22*).

PULP PURIFICATION

The purification of the pulp in a continuation of the process started in the pulping digester. Each depends upon the other, and to make continuously a good quality of pulp, all the steps must be under integrated control. In fact, the operation does not stop here, but the control of the chemical conversion processes is dependent upon the quality of the pulp and, vice versa, the desired properties of the end product dictate the operations all the way back to the wood.

The cooking operation should be so carried out that the maximum removal of noncellulose components takes place in this operation with a carefully controlled "degradation" of the cellulose (with respect to average D.P.). The purification stages are designed to complete the job. Modern pulp purification is usually a three or four-stage treatment, involving chlorination, alkaline extraction, sodium hypochlorite bleaching, and/or a final chlorine dioxide treatment. Sometimes, in certain grades of sulphite pulps the hypochlorite stage is omitted. For a mill of average size (200 tons) each purification stage represents a capital investment of $250,000 to $300,000.

The chlorination stage converts remaining lignin and other minor amounts of colored residues into products that may be dissolved out by washing and alkaline extraction. The principal objective of alkaline extraction is to remove short chain polysaccharides, including as much of the remaining noncellulose compounds as possible and to leave the cellulose fiber in a good "reactive" state for the conversion reactions. Present day practice is mainly toward hot alkaline extraction, which results in better diffusion of the alkali-soluble products from the fiber. Also, economics favors the hot over the cold alkaline treatment.

The final one or two bleaching stages improve the color and remove final impurities. The sodium hypochlorite stage is carefully controlled by buffering to hold degradative oxidation of the fiber to a minimum. It is the most sensitive step with respect to bringing about changes in chain length, the drop in viscosity here being much greater than in any of the other stages. As is well known, a properly controlled chlorine dioxide treatment is very mild and brings about little change in viscosity (molecular size).

CHEMISTRY OF THE FIBER

The continued improvement in the techniques of producing refined pulps owes much to the patient accumulation of fundamental knowledge of the physics, chemistry, and morphology of the fiber. The understanding of the crystalline and amorphous regions of the fiber, the polymolecularity of cellulose and how it is affected by various treatment, the reactivity of cellulose and the types and mechanisms of cellulose reactions, the nature of the chemical components of the wood fiber, and the careful development of suitable techniques for evaluation and analysis all provide the fund of knowledge from which technology develops.

The excellent work of Wise (*23*, *24*) and his associates over the past few years on the chemistry of the polysaccharide components of the fiber contributes much to a better understanding of the problems in the production of refined pulps. The difficulty in establishing a sharp line of demarcation between "true" wood cellulose and the more insoluble hemicellulose is explored by them. This is a problem of direct concern to the producers and consumers of refined pulps since these pulps always contain varying amounts of the difficultly removable hemicelluloses, such as mannan and xylan. As has been mentioned earlier, the presence of these hemicelluloses in the pulp appears to decrease the filterability of viscose and to increase the turbidity of acetate solutions.

Recently, Bradway (*22*), a student of Wise, isolated the haze from both wood pulp and cotton linter acetates. The haze from a commercial acetate consisted of fiber fragments and amorphous material, probably due to incomplete acetylation in certain regions. A careful study of an experimental acetate haze showed that removal of the haze also completely removed all the mannan and xylan originally in the acetate, and hence mannan and xylan appear to contribute to the haze, either directly or indirectly. In the latter case, a possible shielding of a portion of the cellulose from reaction is suggested.

Recent studies (*25*, *26*) on birch holocellulose and its acetates show that direct acetylation of the holocellulose gave a very turbid solution (av. D.P. 193), acetylation of holocellulose after extraction by hot water gave a less turbid solution (av. D.P. 230) and holocellulose extracted by both hot water and 5% NaOH solution gave a clear acetate solution (av. D.P. 281).

However, the separated hemicelluloses can be readily acetylated. The hot water soluble hemicellulose was acetylated by acetic anhydride in pyridine after swelling in 90% formamide (resulting in very little degradation) and fractionated from chloroform solution. This hemicellulose showed a high degree of heterogeneity and a two-colony effect distribution curve. It was separated into nine fractions ranging in "apparent" average D.P. from 21 to 141. The two lowest molecular weight fractions have high (17 to 20%) uronic acid content, exhibit polyelectrolyte character, and have no film-

forming properties. With increasing molecular weight there is decrease in content of uronic acids, arabinose, and galactose and a steady increase in xylose content (from 26 to 52%).

The acetylated 5% NaOH extractable hemicellulose gave, upon fractionation, a normal polymolecularity curve, indicating a greater regularity in structure and composition. Eight fractions were obtained ranging in "apparent" average D.P. from 81 to 246, and in xylose content from 67 to 84.5%, the xylose content rising with increased molecular weight.

Degradative acetylation of the holocellulose by a commercial method gave a product which was fractionated into nine fractions ranging in "apparent" average D.P. from 66 to 370. All fractions contained only glucose, xylose, mannose, and glucuronic acid (arabinose, galactose, rhamnose, and galacturonic acid were lost in the degradative acetylation). With increasing molecular weight, the glucose content of the fractions increased from 53 to 85.3%.

However, the role of xylan and mannan in relation to cellulose acetate properties is not yet clearly defined. This is further indicated in a recent study by Steinmann and White (*27*) of the cause of very high viscosities of concentrated acetate solutions. They found a correlation between viscosity on the one hand, and gamma-cellulose, pentosan, and mannan content on the other. The acetylation process appears, however, to reduce the pentosan content but is considerably less effective in removing mannan, indicating that the mannan may cause anomalous viscosity behavior.

The possible shielding effect of hemicelluloses already previously referred to is further indicated in the chemical microscopy studies of Haas and co-workers (*28*). Their work indicates that in holocellulose, the hemicelluloses are concentrated in the outer layer of the fiber. When holocellulose is xanthated, this layer reacts very quickly but remains intact and does not swell. The protected parts of the inner cellulose layers, therefore, are protected from rapid xanthation and hence, they are only slightly xanthated and remain undissolved.

This helps explain the importance and necessity of uniformity in production of refined pulps. If woods of different moisture content are cooked, the differences in the impregnation of the chips will produce a non-uniform pulp having poor filtering properties, due to the fact that on xanthation some parts will be under-xanthated and others over-xanthated. Modern developments in pulp manufacture are designed to achieve uniformity of pulp qualities not only in each cook but from day to day. This is done by proper circulation of the cooking liquor and the use of recording and controlling instruments.

The removal of the hemicelluloses depends upon the fact that they are hydrolyzed much faster than cellulose, about 1500 times as fast according to Schulz and Husemann (*29*) and upon their greater solubility in alkali. A proper degree of hydrolytic degradation must, therefore, be achieved in sulphite pulping and in the prehydrolysis stage prior to kraft pulping. This must be in balance with the bleaching and alkaline purification stages.

Another important characteristic of dissolving pulps is its viscosity, which depends upon average molecular size (D.P.). However, pulps of the same average D.P. may differ widely in their molecular weight distribution. Much attention has been given this characteristic. It is generally agreed that too much short chain material is undesirable because of its solubility in alkali, poor film characteristics, and low strength properties. Too much very long chain material may cause spinning and filtering difficulties. The relation between polymolecularity of the pulp and the properties of viscose rayon has been the subject of considerable attention, and certain correlations have been pointed out (*30, 31, 32*). However, Haas, Battenberg, and Teves (*28*) point out that the properties of the product depend upon the molecular weight characteristics of the final product, such as rayon fiber, and that the molecular weight distribution of the pulp is important only if it influences the distribution ultimately reached. They point out that in the viscose process the aging of the alkali cellulose removes most differences in molecular weight distribution. It is apparent that the question of the relation of the polymolecularity of the pulp to the properties of the product awaits further clarification.

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Tenth Plastics-Paper Conference, Brooklyn Law School, Brooklyn, N. Y., November 14–15, 1955.

Forty-First Annual Meeting, Commodore Hotel, New York, N. Y., February 20–23, 1956.

Seventh Coating Conference, Benjamin Franklin Hotel, Philadelphia, Pa., May 7–9, 1956.

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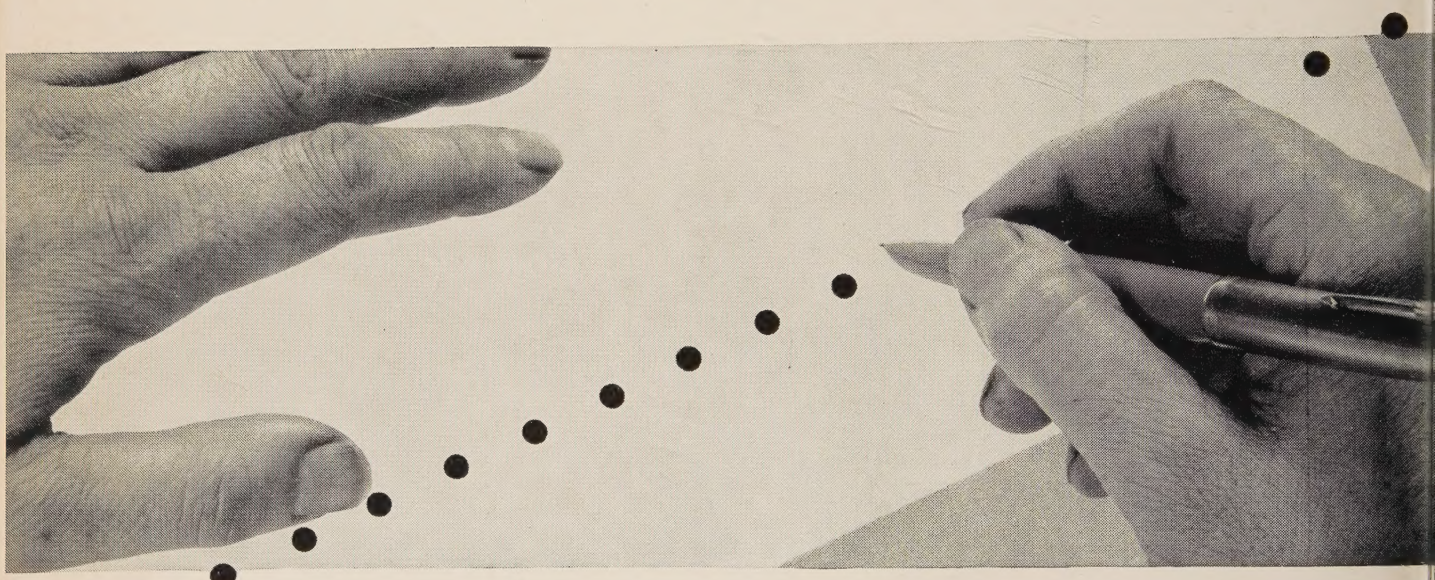

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